

THE
PLEASING PRECEPTOR;
OR *W. Mitchell*
FAMILIAR INSTRUCTIONS

IN
NATURAL HISTORY AND PHYSICS,

ADAPTED TO THE
CAPACITIES OF YOUTH,
AND CALCULATED EQUALLY TO INFORM AND AMUSE
THEIR MINDS DURING THE INTERVALS OF
MORE DRY AND SEVERE STUDY:

TAKEN CHIEFLY FROM THE GERMAN

OF
GERHARD ULRICH ANTHONY VIETH,
MATHEMATICAL TEACHER AT DESSAU;

INTENDED FOR
THE USE OF SCHOOLS,
AND
ILLUSTRATED WITH CUTS.

VOL. II.

Simul et jucunda et idonea dicere vitæ.

HORAT. DE ARTE POET.

LONDON:

PRINTED FOR G. AND J. ROBINSON, PATERNOSTER-ROW,
BY G. WOODFALL, PATERNOSTER-ROW.

1801.

PLACING INSTRUCTION
 IN THE
 NATURAL HISTORY AND PHYSICS

ADAPTED TO THE
 CAPACITIES OF YOUTH
 AND CALCULATED SOLELY TO INFORM AND AMUSE
 IN THE MIDDLE OF THE INTERVALS OF
 MORE SERIOUS AND SEVERE STUDY
 TAKEN DIRECTLY FROM THE GERMAN

GERHARD HERTZ
 (OF DRESDEN)



THE USE OF SCHOOLS

ILLUSTRATED WITH CUTS

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AS the former volume of our work commenced with the apparent swimming of a needle, and a thin bit of metal, we will here say a few words more on the same subject. Our young readers will recollect, it was there observed, that the needle did not properly swim, but was sustained on the surface of the water, because its weight was not sufficient to overcome the cohesion between the particles of the fluid. This may be seen clearly in the following little experiment, which any one may easily try.

Take a glass of water, and lay on its surface a bit of leaf gold, or dutch metal,

about an inch square; the thin metal will not only float, but will even support a small shot or two without sinking; the weight of the first shot will depress the leaf gold in the middle, it is true; but it will be insufficient, to overcome the cohesion of the particles of water through such an extent of surface.

Another circumstance, that our young readers have often observed themselves, probably is to be explained from this cohesion between the particles of water. A fly, that has gotten into a bottle, half full of water, will stand upon the surface of the fluid, rise from it, and fall down again more than once, without sinking. So spiders, gnats, and other insects, will run over the surface of water; not on account of their *specific* gravity, but because their *absolute* gravity is so small. As some of our readers, perhaps, will not clearly comprehend what is meant by the terms *absolute* and *specific* gravity, we shall explain them in the next chapter.

There are even birds, too, of the order of waders, as the rail, that will run over the surface of a lake or pond; but this must not be ascribed altogether to the cohesion of the water, which would certainly give way to a

creature of such bulk. These birds frequent marshy places, and the leaves and stems of the aquatic plants, that grow in the water, and lie along it's surface, no doubt, help to support them, at the same time that they run swiftly; and the slight movement they make with their wings contributes to diminish their pressure on the water.

CHAP. II.

OF ABSOLUTE AND SPECIFIC GRAVITY.

THE terms *absolute gravity* and *specific gravity* very frequently occur in physics: The first is what we express in common life by the word *weight*, and signifies the whole of the power, with which a body presses downward to the Earth. Every particle in every substance is heavy; that is, it has a tendency to fall toward the Earth, or is attracted by the Earth. Now, the greater the number of particles a substance has, the more powerful will be it's tendency toward the Earth: and we express the degree of this ten-

THE PLEASING PRECEPTOR.

dency by certain quantities, on which we have fixed as standards, by ounces, pounds, &c. Thus we say, rightly, this stone *weighs* so many pounds; that pound *weighs* sixteen times as much as this ounce. It is very common, however, to say, that stone is as *heavy* again as this; that pound weight is sixteen times as *heavy* as this ounce; but this, in a physical sense, is improper; the two stones, if they be of the same kind, are equally *heavy*, for they would both fall to the ground from the same height in the same time; and so are the pound weight and the ounce, if they be of the same metal: their heaviness, or gravity, is the same, but their weight is different.

Specific gravity expresses the relative idea of weight, as it regards the bulk of a body. Thus, a cubic inch of lead weighs more than a cubic inch of wood, and a cubic inch of cork weighs less: accordingly we say, the specific gravity of wood is less than that of lead, and greater than that of cork. The specific gravity of a body is in proportion to the density of the matter, of which it consists; and thus we may judge of the density of a substance by it's specific gravity. In lead, the

particles, that compose it, are closer together than in wood; while, in the wood, the interstices between the particles are greater.

To denote the specific gravity of any thing, it is usual to ascertain how much more, or less, a given bulk of it weighs, than an equal bulk of pure water; and, taking the weight of the water as an unit, to express that of the other, by whole numbers, or a decimal fraction, or both. Thus, for example:

The specific gravity of

water being 1.000

That of platina will be 21.000

Very fine gold 19.637

Standard gold 18.888

Quicksilver 14.019

Lead 11.325

Fine silver 11.087

Standard silver 10.535

Copper 8.843

Steel 7.852

Iron 7.645

Block Tin 7.321

Diamond 3.400

Clear glass 3.150

White marble 2.707

Green glass 2.620

Alabaster	1.875
Dry ivory	1.825
Ebony	1.117
Amber	1.030
Cow's milk	1.030
Sea water	1.030
Distilled water	0.993
Dry oak	0.925
Olive oil	0.913
Sassafras wood	0.482
Cork	0.240
Fixed air	0.001875
Dephlogisticated air	0.001320
Atmospheric air	0.001250
Light inflammable air	0.000105

But how is the specific gravity of different substances to be found? Undoubtedly the following method will most readily suggest itself. Reduce the substances to be examined to equal magnitudes, as a cubic inch, for example, and then weigh them. If it be a fluid that is not corrosive, make a cubical vessel of tin, or other metal, which will contain the exact quantity; and thus, with an accurate pair of scales, you may compare the weights of the different matters.

There is a more accurate method, however, and at the same time more easy; and we shall see, in the next chapter, how William was led by his father to the discovery of this.

CHAP. III.

THE BUCKET IN THE WELL.

WILLIAM, one day, observed a man drawing a bucket of water out of a well. As long as the bucket was under water, the man turned the winch very easily; but as soon as the bucket was raised above it, much more exertion was required, and the rope wound slowly and heavily round the roller. "Why is this?" said William to himself. He was aware, that the water in the bucket rendered it heavy, but he did not understand what occasioned the difference in it's weight, and, therefore, asked his father.

"What you have yourself observed," answered his father, "that the water renders the bucket heavy, is perfectly right; and you need only pursue this idea a little farther, to obtain a clear conception of that, of which,

at present, you have only an obscure glimpse. Before the bucket touched the water, was there not water already in the space, which the bucket afterward occupied?

William. "Certainly."

Father. "And this water, no doubt, was sustained, and kept in it's place, by the surrounding water?"

W. "That it must have been, otherwise would have fallen to the bottom of the well."

F. "Can we not deduce from this the weight, that the water, which surrounds a certain space, as in the present case the space occupied by the bucket, would support?"

W. "It will support as much as the weight of the water, that would fill the space."

F. "Very good. Now, you perceive, you are near the solution of your problem: for, while the bucket is under water, does the man find it necessary to lift the weight of the water, that the bucket contains?"

W. "No: since this is supported by the surrounding water."

F. "It is the same with the bucket; for wood, you know, will swim. But when the bucket is half out of the water, and half in,

will the water in the well still support that in the bucket?"

W. "I suppose not."

F. "But it will in part: and what part?"

W. "As much as the space occupied by that part of the bucket, which is still under water."

F. "And what follows?"

W. "That still less and less is supported by the water, the higher the bucket is drawn up; and when, at length, it is entirely above the surface of the water in the well, the man has to draw up the whole weight of the bucket full of water."

F. "But would the surrounding water be capable of supporting a less or greater weight, if any other body, of equal bulk with the bucket, were sunk in it? or, if we still retained the bucket, would the surrounding water be capable of bearing more or less, were the bucket filled with sand, or stones, or lead, instead of water?"

W. "I imagine not. It would still be the same."

F. "Certainly; for the substance that is sunk can neither increase nor diminish the resistance of the water: *the surrounding water*

sustains, as we have shown, just as much, as the water, that would fill the space, would weigh. Whether lead, or stone, or any other substance, occupy this space, does not affect the pressure of the surrounding water; this pressure is proportionate to the dimensions of the substance, not to it's weight."

W. "That is clear."

F. "Well, then; if we weigh a body in an accurate pair of scales in the open air, and then let the body thus weighed be suspended in a vessel of water, will it require an equal weight to counterpoise it as before?"

W. "No; for the water supports part of the weight."

F. "And how much this is, or how much of it's weight it will lose, you already know."

W. "I imagine not. It would still be the same."

F. "Certainly; for the substance that is sunk can neither increase nor diminish the resistance of the water: the surrounding water

CHAP. IV.

TO FIND THE SPECIFIC GRAVITY OF A
SUBSTANCE.

Father. "IF we were to plunge a body into any other fluid, into beer for example, would it not lose a portion of it's weight? and how much?"

William. "As much as the weight of the beer, that would fill the space the body occupies."

F. "Thus, to speak generally, *every body, plunged in a fluid, loses just so much of it's weight, as the fluid, that would fill the space occupied by the body, would weigh.* This is the general law; a law, which we have so readily discovered, or which so palpably offered itself to us, that you will probably be surprised, to find how much may be done by means of it.

"We will first apply it, to compare the specific gravities of different fluids with one another."

William now fetched three tumblers; one of them partly filled with water, another with beer, and the third with milk. In the mean

time Mr. Goodwin got ready his hydrostatical balance, which our readers will see delineated in the vignette underneath.



This balance is constructed on the same principle as a common pair of scales: the tongue, however, does not rise perpendicularly from the beam, but points perpendicularly downward. To one it hangs a scale, which is to contain the weights; from the other is suspended the body, which is to be weighed in the fluid. It is necessary, that such a balance should be very accurate, and very sensible, or capable of turning with a very minute weight, otherwise slight differences would not be perceived. The axis of the beam, on which it rests, has a sharp edge, to render it's friction as small as possible.

To find the specific gravity of different fluids, a glass egg, containing a little quick-

silver, so as to sink it completely in the fluid, may be suspended to one arm of the balance. With such an instrument Mr. Goodwin made the following experiments.

Having first counterpoised this egg in the open air, by putting weights into the scale at the other end of the beam, he then placed the glass of water under it, so that the egg hung in the water. The opposite scale now descended, so that, to restore the equilibrium, it was necessary to diminish the weight in that scale, or to place a weight in the scale over the egg. The loss of the egg in water was two ounces; in milk, about two ounces and one sixteenth; in beer, nearly two ounces and one eighth.

F. "What now may we infer from these experiments, in which one and the same body, weighed in three different fluids, has suffered different losses in weight?"

After a little reflection, William justly answered: "it follows, that as much water, as would fill the space occupied by the egg, must weigh two ounces; as much milk, two ounces and a sixteenth; as much beer, two ounces and an eighth."

F. "Thus we have found the specific gravities of different fluids: for, if we take the

weight of water, as is commonly done, for unity, we need only divide the losses found by the loss in water. So

	B.	Divided by two.
The loss in water = 2		1.0000
milk = $2\frac{1}{8}$		1.0312
beer = $2\frac{1}{4}$		1.0625

“We will now vary the experiment, and endeavour to compare the specific gravities of solid bodies with each other, by weighing them first in the air, then in water.”

William collected different matters; a flint; a piece of brick, a bit of iron, and other things. The flint weighed ten ounces and $\frac{1}{8}$ in the open air; but when it was suspended in the water, it was necessary to take four ounces out of the scale, to restore the equilibrium. Thus much, therefore, it lost of its weight.

F. “What do we learn from this loss of weight in the stone?”

W. “The weight of the water that would fill the space occupied by the stone.”

F. “From this can we not easily compare the specific gravity of the stone with that of water?”

W. “The stone weighs 10 ounces and $\frac{1}{8}$ an equal bulk of water would weigh four

ounces: I have only to reckon, therefore, how many times the latter is contained in the former. Thus 10.125, the weight of the stone, divided by 4, the weight of the water in ounces, will give 2.531: so that the specific gravity of flint is to that of water as 2.531 to 1.000."

F. "Thus you may learn the general rule for finding the specific gravity of a body by weighing it in water."

W. "The weight of the body in air must be divided by it's loss in water; or, by the weight of an equal bulk of water, which is the same thing."

F. "If a body had just the same weight as an equal bulk of water, it would be completely immersed in it, but would not sink to the bottom; so that it would remain at rest, wherever you chose to place it, at the bottom

CHAP. V.

HOW DEEP DOES WOOD SINK IN WATER?

Father. "In the experiments we have made, we have hitherto taken no bodies, but such as completely sunk in water; but some bodies, you know, will not wholly sink in water; as a piece of wood, or a hollow vessel.

will sink only in part. Now, could we employ such bodies as these, to find either their own specific gravity, or that of fluids?"

William. "That is a question, I am not yet prepared to answer."

F. "You do well, William: it is better to confess this, than to give any answer, that comes uppermost, as too many do, lest the person who questions them should suppose, that they know nothing about the matter. I will endeavour, therefore, to lead you to the point. Why does a stone sink in water to the bottom?"

W. "Because it is heavier than an equal bulk of water, and consequently does not lose the whole of it's weight."

F. "If a body had just the same weight as an equal bulk of water, it would be completely immersed in it, but would not sink to the bottom; so that it would remain at rest, wherever you chose to place it, at the bottom of the water, in the middle, or at the top."

W. "That I conceive; for it would be just the same thing, whether the place were occupied by such a body, or by water."

F. "Of this you may very easily convince yourself. Take a bit of wax, make a ball of it, and thrust into it as many small shot, as

will make it weigh exactly as much as the water, that would occupy it's space; you will then be able to place it in any part of the vessel of water, without it's either rising or sinking."

William tried the experiment, and found it succeed.

F. "Now, as the pressure upward of the surrounding water equals the weight of the water displaced by the immersed body, or that which would fill the space this body occupies, what would be the consequence, if a body of a lighter kind, as a piece of wood, were completely immersed?"

W. "It would be forced upward by the surrounding water."

F. "Why?"

W. "Because the weight of the water displaced, consequently the pressure of the surrounding water, exceeds the weight of the wood."

F. "The two powers, that are opposed to each other, then, are the whole absolute weight of the wood, which presses downward, and the pressure of the surrounding water, acting upward. When, therefore, will the wood remain at rest?"

W. "When the two powers are in equilibrium; that is, when the whole weight of the wood, and the pressure of the surrounding water, are equal."

F. "But the latter equals the weight of the water displaced. Thus it is easy to determine, how deep such a body will sink."

W. "Certainly: *it must sink, till the water displaced equals the absolute weight of the body.*"

F. "It must be the same with any other fluid. If, therefore, we immerse such a body in two fluids differing in specific gravity, as beer and water for example, will it sink equally deep in both?"

W. "No: it must evidently sink deeper in the lighter fluid; deeper in water, than in beer."

F. "Thus we have the means of comparing the specific gravity of different fluids. Now suppose, that the part of a given body immersed in one fluid was a cubic inch, in another fluid two cubic inches, what might we infer?"

W. "That one cubic inch of the former fluid weighed as much as two cubic inches of

the latter; namely, just as much as the whole weight of the body partly immersed."

F. "Consequently it's specific gravity must be double: and so in every other case. The less space of a fluid is necessary, to obtain a given weight, the greater must be the specific gravity of the fluid: or, as it is commonly expressed, *in equal weights, the specific gravities are in the inverse ratio of the spaces occupied by the bodies.* Is this clear to you?"

W. "Perfectly."

F. "On this principle are constructed the instruments called *hydrometers*, which are used to prove or ascertain the strength of spirits, try the strength of wort, and examine the saturation of brine in salt-works. The deeper the hydrometer sinks in spirits, the better they are: in worts and brine, the contrary."

W. "How are these hydrometers constructed?"

F. "They are commonly hollow balls of glass, with a smaller ball, containing quicksilver at bottom, and a slender tube at the top. The tube, or stem, is graduated, that the depth, to which it sinks, may be known.

Here are two; one made for spirits, the other for worts. (See the preceding vignette.)

"These hydrometers, however, that I have here, are merely sufficient to show us, that one fluid is lighter or heavier than another, but not how much. If we would examine the proportions, that the specific gravities of fluids bear to each other, with such instruments, the bulk of the immersed parts must be accurately compared, and the divisions on the tube made accordingly."

W. "How is this accurate measurement and division to be accomplished?"

F. "The irregular shape of the common hydrometers would render a mathematical measurement too difficult; it is performed, therefore, by the help of weights. I will try, whether I can make this clear to you."

CHAP. VI.

THE HYDROMETER.

Father. "SUPPOSE, to take at first easy numbers, we would graduate an hydrometer so, that it should indicate specific gravities

in the proportion of 10, 9, 8, nearly as water, oil, and spirit of wine. In water, the specific gravity of which we take as ten, the hydrometer sinks to this point, which I mark on the stem: now, will it sink deeper, or less deep, in a fluid of the specific gravity of 9?"

W. "It will sink deeper."

F. "I have already observed, that the bulks immersed are in the inverse ratio of the specific gravities, or densities; the weight of the instrument, and consequently of the fluid displaced, remaining the same. How then will you calculate the depth, to which the hydrometer must sink in the second fluid?"

W. "I should calculate thus: as 9 is to 10, so must the bulk immersed in water be to the bulk immersed in oil."

F. "Very right. If, therefore, I would sink the instrument as deep in water, as it would sink spontaneously in oil, must I not add more weight to it?"

W. "Certainly."

F. "But how is the weight required, to sink the instrument as deep in water, as it would sink of itself in oil, to be found?"

This William was not able to answer immediately.

F. "You have already said, that the parts immersed must be as 9 to 10: if, therefore, we would sink the instrument in water in both these degrees, must not the weight of water displaced in the two instances be as 9 to 10?"

W. "To be sure."

F. "And consequently the weight of the instrument at first to it's weight when increased as 9 to 10?"

W. "So I conceive."

F. "You are now able to tell me how much the original weight of the instrument must be increased?"

W. "A ninth part."

F. "Now, if we take the third fluid, the density of which is to water as 10 to 8, how must we proceed?"

W. "As before. The bulks are as the inverse ratios of the densities, the weight of the instrument remaining the same; that is, as 8 to 10."

F. "And If I would sink it so deep in water, to mark the degree, how should I find the weight, to be added to the instrument?"

W. "The original weight must be to the increased weight as 8 to 10; or the original

weight must be increased by the addition of $\frac{1}{8}$ or $\frac{1}{4}$."

F. "Thus we have found a method of marking on the stem of the hydrometer degrees, that will give the *proportions of densities*, or specific gravities. Namely: the hydrometer is first to be weighed as accurately as possible in the air: it is next to be immersed in water, and the point to which it sinks is to be marked: and then the weight of the instrument is to be increased by the addition of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, and so on, marking each time the depth to which the stem sinks. Thus we have the hydrometer graduated for fluids, that are lighter than water, and the degrees may be marked in an ascending scale, 0, 1, 2, 3, &c. In this case, when the hydrometer sinks to 0, the specific gravity of the fluid is as 10, or 1.0; when to 1, as 9, or 0.9; when to 2, as 8, or 0.8; when to 3, as 7, or 0.7; and so on.

"I have taken these numbers, that you might find less difficulty in the investigation; but in practice much smaller divisions are required. Instead of denoting the specific gravity of water by 10, we might take it at 100, and increase the weight of the hydrometer

by $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, and so on; marking these smaller degrees on the stem as before, from below upward, with 0, 1, 2, 3, 4, &c.

“In this case, when the hydrometer sinks to 0, the specific gravity of the fluid is as 100, or 1.00; when to 1, as 99, or 0.99; when to 2, as 98, or 0.98; and so of the rest. If the instrument be large enough, the divisions may be made to thousandth parts: but I need not go farther, as, no doubt, you already see how the process is carried on.”

W. “I see, it is true.”

F. “But, you would say, you have it not all clear before your eyes. The fact is, my dear William, things that require some reflection, should be gone over more than once from the beginning, that the whole chain of reasoning may make a more distinct impression on the mind. Sit down, therefore, and write all that you have retained; you will find this a good exercise both of your memory and reflection.”

William immediately followed his father's advice, and took the same method on other occasions. Many of our young readers, we hope, are not averse to reflection, and will do the same. That they may be the more ready

to pursue this plan, they should bear in mind, that it's utility is not confined to the case that they may have in hand. To instance in the present example: the use of considering and weighing thoroughly the doctrine there given respecting the hydrometer, though it is pleasing to know more of such a common instrument, and be better acquainted with it's principles, than most who use it, does not stop here; for, by it the mind acquires a degree of facility in forming just conceptions, making proper comparisons, and drawing right conclusions, in similar cases; and, even, in all cases, the habit of reflection is strengthened and improved by it. The propositions of *hydrostatics*, so the science of the equilibrium of fluids is called, are particularly calculated to exercise reflection; we will, therefore, pursue the conversation between William and his father a little farther.

CHAP. VII.

CONTINUATION.

Father. "WE found yesterday how a hydrometer for lighter fluids was to be graduated, so as to show the proportions of dif-

ferent specific gravities; but how should we proceed for heavier fluids?"

William. "No doubt in the opposite way."

F. "You mean, that the weight of the instrument must be gradually diminished. Suppose we wanted the hydrometer to indicate specific gravities proportioned to another as 100 to 101, taking the first for that of water, we must here proceed as follows:

"The part of the hydrometer immersed in water must be to that immersed in the heavier fluid as 101 to 100, or in the inverse ratio of their specific gravities. If the instrument were to be immersed in water no deeper than in the heavier fluid, the weight of the water displaced must be to that ordinarily displaced by the instrument as 100 to 101: for which purpose the original weight of the instrument must be proportionally diminished. What follows from this?"

W. "The original weight must be diminished $\frac{1}{101}$."

F. "So, if we would find the point for a specific gravity of 102, the original weight of the hydrometer must be to it's diminished weight as 102 to 100. Consequently ——"

W. "The original weight must be diminished $\frac{2}{101}$."

F. "I need not proceed any farther, as you must be aware, that the degrees for other specific gravities must be determined in the same way. Thus, if a 0 be put against the place, to which the hydrometer sinks in water, and the other degrees be marked in a descending series 1, 2, 3, and so on, these degrees will mark proportional diminutions in the specific gravity of fluids: 0 being equal to 100, or 1.00; 1, to 101, or 1.01; 2, to 102, or 1.02; 3, to 103, or 1.03."

W. "But it seems to me, that it must be very difficult, to divide an hydrometer accurately in this way."

F. "You are very right, for great nicety is required, to increase the weight of the hydrometer precisely $\frac{1}{99}$, $\frac{2}{98}$, $\frac{3}{97}$, or to diminish it $\frac{1}{101}$, $\frac{2}{102}$, $\frac{3}{103}$, and so on.

"In fact, if we did not think much of the trouble of a little calculation, we might go to work in a much more certain way. We need only make an hydrometer with a little cup at the top, into which we might put weights, to sink it to a given depth in all fluids. Thus, if I had an hydrometer weighing exactly 500 grains, I should make a mark on the stem, to which it should always be im-

mersed. Now, supposing, that I must put into the cup thirty grains, to sink the hydrometer to this mark in pure water; the water displaced would weigh 530 grains: supposing too, that sixty grains would be required, to sink it to the same mark in a solution of salt; the brine displaced must weigh 560 grains. Consequently, as an equal bulk of the instrument was immersed in both cases, the absolute weights of fluid displaced must be as 530 to 560; and, as it is usual, to take the weight of pure water as the unit, or standard, we have only to calculate, by the rule of proportion, as 530 is to 560, so will one be to the specific gravity sought.

$$530)560(1.056$$

$$\underline{530}$$

$$3000$$

$$\underline{2650}$$

$$3500$$

$$\underline{3180}$$

$$320$$

“ This is evidently a better way of proceeding, than the troublesome, yet not certain method of graduating the stem.”

W. "Why, then, do people graduate the stem?"

F. "Because, when once the instrument is finished, no farther calculation is required; nothing more being necessary, every time you use it, but to read the degree marked on the scale, which is certainly the easiest way. Different hydrometers have been constructed, in which both these methods have been united to a certain degree; but for those, who wish for the greatest possible nicety, far the best is that invented by Mr. Nicholson, on the principle above mentioned, which is ingeniously contrived to determine the specific gravities of solids also.

"Now you have thus gone through the construction of the hydrometer, you will probably find the following story both instructive and entertaining."

CHAP. VIII.

THE CHEAT DETECTED.

F. "ABOUT two hundred and fifty years before Christ, a celebrated mathematician, lived at Syracuse, named Archimedes, whose inventions and writings were of great service

to his fellow citizens, as well as to the science. This ancient may be called the father of hydrostatics, for he wrote, among his other works, a book on bodies that swim in water. The story, with which I am now going to acquaint you, is not to be found in what we have of this book however, but in another ancient work, in Vitruvius on Architecture. Many, indeed, hold it to be a fable, because it is not come down to us in the writings of Archimedes himself: but certainly this is not a sufficient reason for deeming it untrue, particularly as we have not the works of Archimedes entire. At any rate, it is neither improbable in itself, nor unworthy of the man. If you have any inclination to try whether you understand latin enough to translate it yourself, reach me down that great book."

William was very ready to do this, as he had found, on more occasions than one, that there were many things new to him in similar old books. Accordingly, having taken down Vitruvius, and turned, as he was directed, to the third chapter of the ninth book, with his father's assistance he read as follows.

“ Among the various and admirable inventions of Archimedes, the following appears to me the most ingenious.

“ When Hiero of Syracuse was exalted to the throne for the rectitude of his conduct, he resolved to dedicate a crown of gold to the immortal gods. Having agreed with a goldsmith for the fabrication of this crown, the due quantity of gold was accurately weighed, and delivered to him. At the appointed time the crown was finished; the king was satisfied with the workmanship; and the weight was found to be just. It was not long, however, before a report was spread, that the workman had purloined a portion of the gold, and substituted silver in it's place.

“ Considering his own honour involved in the question, Hiero was greatly incensed, but knew not how the truth was to be discovered. Accordingly he referred it to Archimedes.

“ While Archimedes was endeavouring to devise some means of detecting the cheat, he one day observed, as he was going into the bath, that the water flowed over the brim, in proportion to the space occupied by his body. This instantly suggested to his mind

a solution of the problem; and, overcome with joy, he sprung out of the bath, and ran home, naked as he was, crying, as he ran, 'I have found it! I have found it!'

"In consequence of this discovery, we are informed, he took two masses, one of gold, the other of silver, each exactly equal in weight with the crown; filled a vessel to the brim with water; and let the mass of silver down into the water by a string. Of course a quantity of water ran over, equal to the space the silver occupied. Then, having drawn out the silver, he measured the water, that had run over, and poured it in again, so that the vessel was filled to the brim as before. Hence he calculated how much water answered to a given weight of silver. This being ascertained, he let down the mass of gold into the full vessel, in the same manner, and, after he had taken it out, measured the water that had run over. This, he found, was not equal to the former quantity, but so much less as the mass of gold was less than the mass of silver of equal weight. Having filled the vessel a third time, he put in the crown itself; and it appeared, that more water ran over, than had done on the immersion of an

equal weight of gold. From the quantity of water, that ran over when the crown was put in, more than the mass of gold caused to overflow, he found by calculation the weight of the silver mixed with the gold, and thus the cheat of the goldsmith was detected."

F. "So far Vitruvius. I must observe to you, however, that Archimedes took it for granted, in his experiment, that gold and silver melted together would occupy just the same space, as the two unmixed: but this was an error. In most cases of melting metals together as well as in solutions, and mixtures of other kinds, the compound occupies less space than the ingredients would have done separately, one of the substances penetrating into the interstices of the other.

"If gold and silver did not penetrate each other, the adulterated crown would have been larger, and Archimedes would have found, that the goldsmith had employed more silver, than his experiment led him to conclude. But in fact the crown was less, than it ought to have been on his hypothesis; so that he estimated the silver below its real quantity, doing the goldsmith no wrong at least by his ingenious discovery."

CHAP. IX.

HOW MUCH SILVER WAS THERE IN THE CROWN?

Father. “VITRUVIUS, whose account you have just read, merely says, that the crown cost a vast sum of money; *immani pretio* are his words; but he gives us no information concerning its weight, or the calculation of Archimedes. If, however, you would go through the experiment of Archimedes, we might suppose, that the crown weighed twenty pounds, and the water it displaced weighed one pound and a quarter: could you not find from this the difference of specific gravity between the water and the crown?”

William. “As the crown weighed 20lb, and the water, that occupied the same space, weighed $1\frac{1}{4}$ lb, I have only to divide 20 by $1\frac{1}{4}$, and the quotient, which is 16, informs me, that the mixed metals weighed 16 times as much as an equal bulk of water.”

F. “You may remember the difference between gold, and silver, and water, when we

were on the subject of specific gravity the other day [p. 5]; but, as an arbitrary proportion will answer our purpose of explaining the experiment of Archimedes equally well, we will take it in round numbers, reckoning gold twenty times as heavy as water, and silver ten times as heavy. Thus, when Archimedes immersed 20lb. of gold in the water, how much water was displaced?"

W. "One pound."

F. "And when he immersed twenty pounds of silver?"

W. "Two pounds of water."

F. "Well, now we have to find how to compose a mass of gold and silver, which shall weigh twenty pounds, and displace a pound and a quarter of water; in doing which we may reason thus.

"Mere silver we must not take, as it would displace three quarters of a pound of water too much. Is this evident to you?"

W. "Yes; for mere silver would displace two pounds of water, which are three quarters of a pound more than were displaced by the mixed mass."

F. "And mere gold we must not take, for——"

W. "That would displace a quarter of a pound too little."

F. "Should we then take equal parts of each?"

William considered a little, without venturing to answer, for he was at a loss to know how to calculate.

F. "A little calculation will show us, that this would be wrong. Suppose I took ten pounds of silver, how much water would they displace?"

W. "One pound."

F. "And ten pounds of gold?"

W. "Half a pound."

F. "The whole twenty pounds of the mixture, therefore?"

W. "A pound and half. But this could not be the mixture, as it displaced only a pound and a quarter."

F. "We must proceed in some other way, then; and, I believe, it will not be difficult to find the right. Attend to what I say, and tell me what you think."

"The quantity of gold, that we must take, would displace less water, than a piece of the mixture of equal weight. Is it not so?"

W. "Certainly."

F. " But the silver, that we must take, would displace more water than an equal weight of the mixture would displace."

W. " That is very clear."

F. " Well, then, if we were to take gold and silver in such proportions, that the deficiency in one case should be equal to the surplus in the other, would they not balance each other? and would not the two together displace just as much water as the goldsmith's mixture?"

" I have found it! I have found it!" exclaimed William joyfully, in imitation of Archimedes.

F. " It is as good as found, indeed: but be not too hasty. Archimedes, when he leaped out of the bath, had probably advanced as far as we have done: but the last step of the process was to be performed in his study, and we must follow his example. How then must I proceed, to take a due proportion of gold, and a due proportion of silver?"

W. " So that the deficiency of water, displaced by the gold, may be supplied by the greater quantity, that the silver displaces."

F. " But twenty pounds of gold displaced a quarter of a pound too little, and twenty

pounds of silver displaced three quarters of a pound too much : was it not so ?”

W. “ We found it so just now.”

F. “ Inequal weights, then, of gold, of silver, and of the mixture, whether they weigh each twenty pounds or not, the difference between the quantities of water displaced by the mixture and by the silver is three times as great, as the difference between the quantities displaced by the mixture and the gold ?”

W. “ Certainly.”

F. “ Well then, if we take three times as much gold as silver, how will the differences be ?”

W. “ They will be equal.”

F. “ The gold and silver must be taken, then, in the inverse ratio of their differences ; and thus, in our case, we must take three pounds of gold to one pound of silver. You can now calculate the quantities, I suppose.”

W. “ Yes. Three pounds of gold and one of silver make four pounds ; so the mixture must be three fourths gold, and one fourth silver. One fourth of twenty is five, and three fourths of twenty are fifteen : accordingly there must have been fifteen pounds of gold, and five of silver.”

CHAP. X.

THE WONDERFUL BALLS.

Henry to William.

“ I received much pleasure, my dear brother, from the description, in your former letter, of the simple and judicious method of removing a house. What the mechanic is capable of effecting by means of machines is certainly wonderful: and if the nature of his materials, and the place on which he is forced to stand, did not present him obstacles insurmountable, his mediate powers would be unlimited. Archimedes said to the king of Sicily, when struck with astonishment at the effects produced by his machines: ‘give me but a place out of the Earth to stand on, and I will move the World.’ The expression was certainly strong; and Archimedes well knew, that it was impossible to construct wheels and a lever capable of executing the gigantic thought. The king might have answered, ‘ I cannot give you what you require to move the Earth, it is true; but, if

you would let me see a proof of your art, there is the Moon for you to move, which is not a fortieth part so big as the Earth: for this you may take my kingdom to stand on, which is perfectly detached from the Moon.'

The great mathematician, however, meant, no doubt, that machines for moving any weight might be invented in theory, though they could not be executed in practice.

"As you write me in your last letter*, you have become acquainted with Archimedes, and admired the sagacity, with which he detected the cheat of the goldsmith. You know, too, that his experiment was right in theory only; as he presumed, that two metals melted together occupy the same space as they would separately: but this in some cases they are far from doing, as in an experiment I lately saw. Five balls of copper, and one of tin, were cast in the same mould: these were then melted together; and we expected to see six balls of the mixed metal, when this was cast in the same mould as before; but, to our great surprise, the com-

* This letter contained an account of the solution of the problem in the preceding chapter.

pound produced only five balls, though these weighed as much as the former six. Thus it was apparent, that the particles of the melted tin must have insinuated themselves completely into the interstices of the melted copper.

“ Probably you wish to know more of Archimedes. If you request our father, to let you translate the 34th chapter of the 24th book of Livy, you will find many things respecting him, that will afford you much gratification.

“ Farewell, my dear brother, and let me soon have the pleasure of reading another letter from you.”

“ H. G.”

CHAP. XI.

A FRAGMENT OF LIVY.

THE passage in Livy, which William was eager to peruse on the recommendation of his elder brother, will not be unentertaining, we imagine, to our young readers.

“ The city of Syracuse was besieged, both

by sea and land, by the Romans, under the command of Marcellus. These powerful enemies carried on their approaches to the capital of Sicily with every warlike implement, at that time used in sieges. Unquestionably, an enterprize undertaken with such ardour must have been attended with success, had not a certain man lived in Syracuse at this critical period. This was Archimedes : superiour to all men in observing the heavens and the stars, and still more astonishing for his faculty of inventing and managing warlike engines and instruments of defence, by means of which every thing, that the vast exertions of the enemy brought against the city, was destroyed with ease. The walls of Syracuse, which were carried over hills of different heights, many lofty and almost inaccessible places, and others that were low or level, were supplied with warlike implements of every kind under his direction, all being adapted to the exigencies of the place. Marcellus himself, with his quinquiremes, threatened one part of the walls, the foot of which was washed by the waves of the sea. At a greater distance lay other vessels, with archers and slingers, who suffered scarcely any one,

that ventured to show himself on the walls, to depart unwounded. Other ships were made fast, two and two, to the quinquiremes; the oars on one side of each being removed, so that they could lie close together, and be rowed along by the oars on the outward sides. On these ships, thus lashed together, were erected large towers of several stories, and engines to batter the wall.

“ To these naval preparations Archimedes opposed warlike engines of different sizes along the wall. At the distant ships he discharged stones of enormous weight: those that were near he assailed with lighter weapons, plied more briskly. That the besieged might annoy the assailants, without being in danger of receiving wounds themselves, he caused a number of apertures to be made in the wall from top to bottom, through which they could aim their arrows at the enemy unseen. Some of the enemy's ships lay so near the wall, that they could not be hurt by these arrows, which flew over them: but these a more disastrous fate awaited. The bold genius of Archimedes invented powerful engines, by which strong iron chains with large hooks were lowered down from the walls.

These caught hold of the prows of the ships, raised them up on their sterns, and then suddenly let them fall. The terrible shock a ship must receive, thus falling from the height of the wall, with all it's men, and all it's stores on board, may readily be imagined. If haply it fell straight into the water again, the violence of the fall immediately engulfed it in the waves.

“ Marcellus was now convinced, that he could do nothing on the side of the sea, and therefore drew off his forces from this part, that he might make a more powerful attack by land. But here likewise every place was amply supplied with the means of resistance. The fortifications, on which Hiero had for many years employed every care, and much cost; the works, which the incomparable art of Archimedes had erected; and a situation strong by nature; favoured the defence, and frustrated the attack. The foundations of the walls were fixed on a steep rock. This gave the besiegers the advantage, that their missile weapons were discharged with more certainty of execution, and blocks of stone, rolled down, made great havock among the enemy, wherever they ventured to approach.

On the other hand, it was almost impracticable for the besiegers to ascend an acclivity, which was so steep, that every step they took was insecure. The romans, therefore, held a council of war, in which it was resolved, as all their exertions had been frustrated, to relinquish the siege, and content themselves with blockading the city both by land and sea."

Thus far Livy. On this occasion we must observe, that other accounts ascribe to Archimedes a peculiar contrivance, by means of which he did the romans great injury, and compelled them to desist from the siege. It is said, that he erected large burning-glasses, and thus set fire to the roman ships. Livy, however, who, as appears in the above extract; speaks pretty fully of Archimedes and his ingenious inventions, says nothing of these burning-glasses, which were first mentioned by later writers. The fact itself, we must confess, has nothing in it impossible; particularly as the ships lay so near the wall, that they could be taken up by the iron hooks, a subject on which we shall have an opportunity of saying more hereafter; but it is certainly not very probable. Perhaps this part

of the story may have originated from a misconception, or a fault of some transcriber, which will readily account for it. It is not difficult to imagine, that Archimedes may have burned the roman ships by means of darts or arrows carrying fire; which was certainly more easy, than to set fire to them by means of burning-glasses. Were this the fact, some latin author perhaps may have related, that the ships were burned *spiculis ardentibus*, and some transcriber may have written *speculis ardentibus*; instead of those words,

CHAP. XII.

THE BENDING STEEPLE SET UPRIGHT.

WILLIAM was filled with admiration of the great artist, whose genius baffled the efforts of a mighty army. He formed to himself such a lively idea of a huge iron hook descending from the wall, catching hold of a ship, lifting it up into the air, and again letting it fall, so as to dash every thing in it to pieces, that he made a drawing of it, as if he

himself had been present, and which we would lay before our readers, could we answer for it's accuracy. In many books, it is true, we find representations of things, which the artist never beheld; but this is a liberty, in which we will not indulge, as it can lead only to erroneous ideas: we leave it, therefore, to every one's own imagination, to figure to himself the ships, the engines, and the person of Archimedes.

"This is something more than removing a stable!" said William, when he got to the end of the chapter.

"Certainly:" answered his father, who had assisted him in his translation from Livy.

"But I could tell you of other performances by means of mechanics, both in ancient and modern times, at which perhaps you would not be less surprised."

W. "Will you tell me some of them? You know, I like to hear such things."

F. "Very willingly: but first let me ask, do you remember the chief laws of the lever, the pulley, and the inclined plane, which I lately explained to you?"

William had written down these, that he might look at them occasionally, to imprint

them in his memory, and knew them by heart.

W. “ In the lever, and all machines constructed on the principle of the lever, as capstans, winches, wheelwork, &c., to produce an equilibrium, the power and the weight must be in the inverse ratio of their distance from the centre of motion ; that is, inversely as lines drawn from the centre of motion perpendicularly to the direction of the forces.

“ In the inclined plane, the weight is to the power, if this be exerted in a direction parallel to the plane, as the perpendicular height of the plane is to it's length ; if the power be exerted in a direction parallel to the base, as the height is to the base of the plane.

“ In the usual compound pulleys, called tackles, a power can support a weight as many times greater than itself as the number of times the rope by which it is suspended passes round the pulleys.”

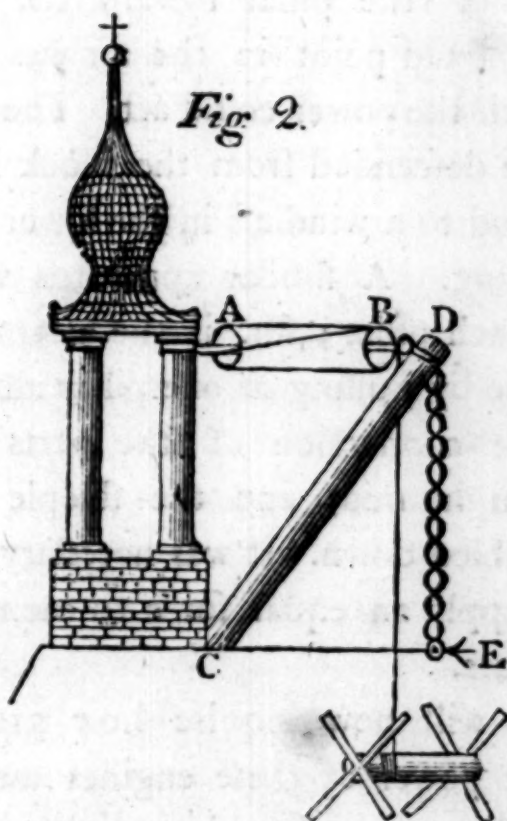
F. “ Very right ; and these few principles will suffice, to give you a general idea of the operation of many useful machines. I will tell you now of a mechanical performance, which, if not to be compared with those of Archime-

des, was at least bold, and executed with success. It is not, however, the greatest, or most celebrated, of modern times. Whoever sees a high tower, which from age, or a defect in it's construction, inclines to one side, so that the upper part threatens to tumble down, will say at the first sight, it must be taken down, and rebuilt in a perpendicular position: the mechanical genius of an able architect alone could form the bold resolution of restoring it to it's perpendicular as it stands. The soldier, it is true, holds up his head, and stands erect, at the word of command: but steeples are more stiffnecked. The greater power of mechanics, however, can force even steeples to obey.

“ The circumstance I am going to relate took place in Hamburgh some years ago. The steeple of St. Nicholas's church in that city is constructed of massy walls to a certain height. The upper part, in which there is a ring of bells, rests on eight pillars. These pillars perhaps were not sufficiently firm at their base, to resist the continued force of the strong westerly winds, so that they acquired an inclination to the east, and this in such a degree, as to deviate near a foot and

half from the perpendicular, which is no trifle. An architect, of the name of Sonnin, undertook to set the steeple upright again. Consider now the difficulties he had to encounter. In the first place, the power required, to give such a vast body the proper direction, could not be small; but this was the least difficulty: in bending a body of such a kind by forcible means, was there not great reason to apprehend, that it would be thrown down? and then, by which most people would have been deterred, it was necessary to apply the force to the upper part of the steeple, to bend it to the western side. Was not Sonnin here almost in the case of Archimedes, when he required a place, from which to move the Earth? Where, at such a height, was he to find a firm station for his machinery? The point, from which the power must act, was high in the air; and to erect a scaffold of such a height, with strength sufficient for the purpose, would have required an expense much too great. Sonnin surmounted this difficulty by very simple means, suggested to his mind probably by the tackling of ships. The most essential parts of it I will exhibit to you in a figure; whether the steeple be like that of

St. Nicholas, or not, is little to the purpose.



“ A strong beam, C D, was made to bear against the base of one of the pillars at C, where it was firmly supported, in an inclined position. It's upper end, D, was connected with the top of the pillar by means of a tackle, A B, and secured below by strong iron chains, descending perpendicularly from D toward E. These chains held the beam fast, so that the

action of the tackle could not move it toward the pillar; consequently it must move the head of the pillar toward the beam. Thus the fixed point in the air was found, from which the power could act. The end of the tackle descended from the block B, and was fastened to a windlass in the lower part of the building. A similar apparatus was applied to each pillar; for, if the attempt had been made by pulling at one pillar alone, no doubt the connection of the parts would have been injured, and the steeple would have tumbled down. It was necessary, therefore, to apply an equal force to each of the eight pillars.

“ We will now inquire how great the collective power of these engines may have been. Suppose we reckon eight men to each windlass, and consider each as applying a power of 20 pounds to his handspike. What was the amount of the whole power applied to each windlass?”

W. “ Eight times 20, or 160 pounds.”

F. “ We will suppose, too, that from the part where the men grasped the handspikes to the axis was six times as long as the semidiameter of the windlass: how much would this increase the power?”

W. "Six times: so that it would be 6 times 160, or 960 pounds."

F. "If we farther suppose, that one of the blocks had three sheaves, the other four, so that the rope passed seven times round them, what follows?"

W. "That the power was increased seven times; consequently would be seven times 960, or 6720 pounds."

F. "Now, as there were eight such machines, one for each pillar, how great would be the power of the whole apparatus?"

W. "Eight times 6720, or 53760 pounds."

F. "Such a vast power must certainly have been more than sufficient; for it was not required, to lift the whole weight of the steeple, but only to move it about eighteen inches to one side. The weight to be moved was still supported by the pillars; so that the machine had only to overcome it's lateral pressure, and the friction and pressure of the joints of the masonry that were separated."

CHAP. XIII.

OF THE FIGURES AND COLOURS OF
CLOUDS.

No doubt, my young readers, you have often beheld with delight the beautiful appearances, that the clouds daily exhibit. I can remember well the pleasure I felt, at an early age, in contemplating those floating masses of infinitely diversified shapes, colours, and motions. We are so much accustomed to the sight, however, exhibited gratis too, that we pay it less attention than it deserves. Clouds distinguished by their splendour are perhaps looked at once, and admired; though their splendour is only borrowed, like that of many persons of distinction: while those, that appear in more sober colours, pass unnoticed, like one of the crowd; and we never deign to cast an eye upon them, unless when we wish to know, whether we may take a walk without danger of a shower. The clouds, however, deserve to be considered as objects of natural philosophy, and

objects by no means destitute of amusement.

We will first consider their *figure*. This seems to be altogether casual and irregular; yet, if we examine them more minutely, particularly those in the higher regions, we shall find them more regular, than any one at the first view would suppose. They appear, in fact, to form parallel circles round the Earth, for the most part cut perpendicularly to it. These parallel circles, indeed, are often thrown into disorder by the winds; but, by a little attention, we may soon discern their original direction. Each parallel circle consists of several clouds, as a file of foldiers consists of several men. This form is apparently not owing to the wind, which frequently has a different direction; but to an undulating motion of the air, resembling that of water, when a stone is thrown into it. We may observe, too, in these zones of clouds, that their progress is partly a parallel advance in a particular direction, partly a circular motion, as round a centre. In clouds that hang low this regularity is not to be observed; for, as they are so near, we see too small a portion of them,

and in general their motion is more liable to be disturbed.

Single clouds, particularly in the lower regions of the atmosphere, exhibit the most diversified forms, baffling all description. Sometimes they rest on the horizon, towering over one another like snow-capped mountains; at others, they fly about, ragged and dispersed, in a thousand shapes, from which the imagination may figure out camels, or ouzels, with Hamlet, or all the monsters of romance. They chase each other, collect into one mass, or break into fragments, varying their outlines every moment. The lower edges next the Earth are commonly sharper, and less broken than the upper, which are ragged, like rocks, trees, or the like.

It is very entertaining, to observe the changes, which they are continually undergoing by imperceptible transitions. The air is seldom so completely still, that a cloud, on which you have fixed your observation, retains it's form unchanged many minutes. But changes in the forms of clouds are not occasioned by the motion of the air alone; evaporation and condensation have consider-

able effect in producing them. If you fix your eye attentively on any particular part of the upper edge of a cloud, you will often clearly perceive a vapour ascending from it, as steam does from boiling water, with a whirling motion, which is perceptible even to the naked eye, though more so to a telescope of moderate power; and this vapour either separates from it, preserving a visible form, or is gradually attenuated, and vanishes from the sight. This pleasing appearance I have observed particularly in the month of march, toward noon, when the previously cold cloud has become warmed by the Sun approaching the meridian, in places where the edge of the cloud, whitened by the Sun's light, has had a clear deep blue sky for the back ground.

As parts of clouds, or even the whole, are sometimes dissipated by evaporation, and become invisible; at other times they arise, and are enlarged, apparently out of nothing, of which we shall say more presently.

But who can describe the variety of their *colours*, with all their tints and shades! What painter can imitate them with earthy pigments, since he cannot dip his pencil in

ethereal light ! To day, while a beneficial rain moistens the dry earth, the whole horizon is covered with one uniform dusky gray. Yesterday, small, white, fleecy clouds floated over the blue sky, and, collecting in the west, announced to day's rain. Dusky, leaden, and brown thunderclouds hung below, threatening to fall in a body on the ground, as too heavy for air to support. Again, at sunset, or at sunrise, what a beautiful display of hues ! Here float rose-colour, purple, red, violet ; there, nearer the horizon, are the blue mountains of clouds skirted with gold ; and in the higher regions float streaks of fire. The colour and splendour of the clouds evidently depend on their position with respect to the Sun and the observer's eye, and partly to the qualities of the vapour, of which they consist ; as they are all occasioned by the various refraction or reflection of the rays of light.

CHAP. XIV.

OF THE MAGNITUDE AND WEIGHT OF
CLOUDS.

CLOUDS evidently differ in size. There are small clouds, that appear like flocks of wool; and large ones, that cover whole regions. Men have already attempted to measure clouds; and though little accuracy can be expected in such an undertaking, we may, perhaps, form some conclusions respecting their bulk.

“How can clouds be measured?” perhaps my young readers will say.

In small clouds, their magnitude may be inferred from the extent of the shadow they cast on the ground. “But,” you will say, “the shadow may be much larger than the cloud itself; for, if I hold a piece of paper between a candle and the wall, the shadow is much larger than the paper.” That is true; and such of you, as have learned the elements of geometry and optics, will know, that the shadows will be in proportion to

the squares of the distances; so that, for example, if the wall be three times as far from the candle as the paper is, the shadow will be nine times as large as the paper. But with regard to clouds, and in general when the light comes from the Sun, we may consider the shadow as exactly equal in breadth to the body that occasions it; for the Sun is at such a distance from the object, that the difference between it's distance and that of the earth from the Sun cannot come into calculation. The thickness of a cloud can be observed best by ascending high mountains. You may often see a cloud hanging on the side of a mountain over you. When you ascend to a certain height, you will find yourself in a thick mist, which is nothing more than the cloud: and, by continuing your progress through this mist, you will find, at length, the clear sky over your head, and the cloud beneath you. Thus you may easily calculate it's thickness.

We may form some conjecture also of the *weight* of a cloud of a given thickness. Suppose a cloud be 6000 feet long, 6000 feet broad, and 1000 feet thick; allowances being made in this calculation for the irregu-

larity of it's shape, so that what is left in one part may be compensated in another: the cubical contents of this cloud will be 36000000000 feet. If we reckon the weight of a cubic foot of the air, in the region where this cloud is, to be one ounce; and we know, by the laws of hydrostatics, which we had occasion to investigate in a preceding chapter, that it can remain stationary only where it's specific gravity is exactly the same with that of the air, the space of which it occupies; we shall find the weight of the cloud to be 2250000000 pounds.

If we consider the vapour, which properly constitutes the cloud, to be only a thousandth part of the weight, which must be a very thin cloud however, we shall have for the weight of the actual substance of the cloud 2250000 pounds. Muschenbroek reckons the weight of the vapour at one-tenth, which would be a hundred times as much as we allowed in our instance.

CHAP. XV.

OF THE HEIGHT AND DISTANCE OF
CLOUDS.

To ascertain the height of clouds with tolerable accuracy, unless it be such as we can reach by ascending mountains, is scarcely practicable. The mere eye informs us, that they float at very different distances from the surface of the Earth. Heavy thunder-clouds hang very low: even on moderately high mountains, you may sometimes see the lightning beneath you. This beautiful natural phenomenon may be seen on the Brocken; and as this mountain is not much above 5000 feet in perpendicular height*, it is evident, that thunder clouds may ap-

* The Brocken in Saxony, like many other high mountains, has been reckoned by many much lower than it is. Its summit has been estimated by observations with the barometer at 3000 feet above the level of the town of Wernigerode; but Mr. Kise has found it, by trigonometrical measurement, to be 5300 feet;—no trifling difference.

proach within one or two thousand feet of the surface of the Earth.

The light, white, fleecy clouds float at a very great height. Saussure, who ascended the highest mountain we know in the old world, beheld them apparently as high above him on it's summit, as if he had been on the plain ground. Heavier clouds than these, too, must be found higher than the summits of the loftiest mountains; for they let fall snow upon these summits. Bouguer observed clouds in South America at least 800 fathoms, or 4800 feet, above the summit of Chimborasso, and this mountain rises more than 19000 feet above the surface of the sea.

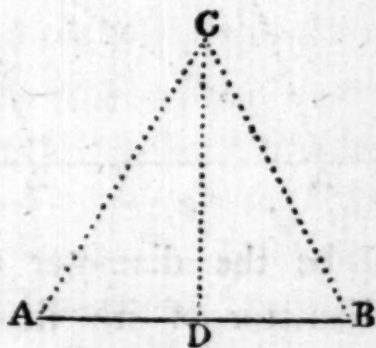
Perhaps some of my young readers will ask, "How can we measure the height of clouds, which we cannot reach?" Such, however, as have studied geometry, will know, that more difficult problems may be solved by it's aid. In theory, the matter in question is easy enough; yet we cannot promise ourselves much accuracy, when we attempt to put it into practice. This, however, is owing to no defect in the science of geometry: the difficulty lies in determining

a certain point in a cloud, and observing it from two stations. As the whole figure of the cloud is so indeterminate, and it's outline so irregular; as a point, on which the eye may fix at one place, may be concealed by other parts of the cloud from a station a thousand yards off; and as the form of the cloud is continually changing; it is obvious, that two persons cannot fix on a point to be observed with any great degree of certainty.

If they did succeed in fixing on a determinate point in the cloud, the two observers should station themselves at some distance from each other, where the space between them could easily be measured; observe the point fixed upon at the same instant; and take the angle, which a line drawn from this point to the observer's eye would make with the line drawn from one station to the other. From the two angles thus taken, and the measure of the line between them, the perpendicular height of the point observed might be found. The instant when the observation is to be made from both stations must be settled; and each observer must be provided, for the purpose, with a watch.

that tells seconds, that they might make their observation at the same second of time; or one may give the signal to the other by discharging a pistol. The distance between the two stations must not be too small.

As we presume some of our readers are acquainted with trigonometry, we will add a concise account of the manner of calculating the height. Let C, in the triangle beneath, be the point of the cloud observed, A and B, the observers' stations.

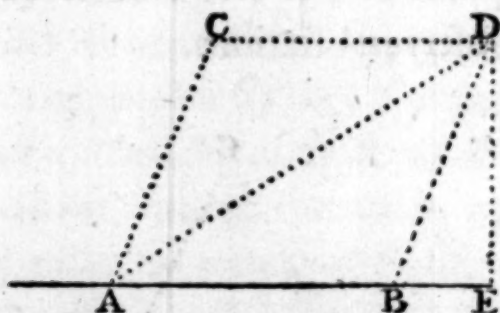


The angles at A and B, and the length of the line between them, are known. Hence the angle at C may be found, and then one of the other sides, for instance A C, by the proportion, as the sine of C is to the sine of B, so is A B to A C. When you have thus found A C, the side C D, in the rect-

angular triangle $A C D$, or perpendicular sought, may be calculated by the proportion, as the sine of D is to the sine of A , so is $A C$ to $C D$.

By this mode of measuring, Riccioli found the height of clouds not above 25000 feet.

However, as this operation gives only an approximation to the true height, perhaps the following mode might be advantageous.



Let $C D$ be the diameter of a cloud; $A B$, the diameter of it's shadow on the ground, which must be equal to $C D$, as the rays of the Sun, $C A$ and $D B$, are parallel. The angle $C A B$ is known, being that of the sun's height above the horizon: so is the angle $A B D$, as, with the former, it must make 180° . Now, while one person measures the line $A B$, let another take the angle $D A B$. Thus, in the triangle $A B D$, we have the side $A B$, with the two adjacent

angles, whence the third angle D , and the side $B D$, may be found. Now, in the rectangular triangle $B D E$, we have the side $B D$, the angle B , being that of the Sun's altitude, and the right angle E , known. Hence the side $D E$ may be found. This proceeding, I confess, will be liable to the same difficulties in practice as the former; but it has this advantage, that the point D is to be observed only from one station, A .

There is another mode of finding the height of a thundercloud, which happens to be over-head, namely, by observing the interval between the lightning and the thunder. From the astonishing velocity of light, the flash may be considered as seen the instant it takes place; but sound requires a second of time to travel the space of 1000 or 1200 feet: if, therefore, five seconds elapse between the time of our seeing the flash of lightning, and hearing the clap of thunder, we may infer, that the cloud is about 6000 feet distant. From the colour of clouds, too, we may form some estimation of their height, as Bernoulli observed, by noticing the time that elapses between the setting of the Sun, and the vanishing of the

redness of the cloud: but from this method we cannot expect more accuracy, than from those already mentioned. It may be inferred, however, by the methods here given, that the greatest height of the clouds does not exceed four or five miles.

CHAP. XVI.

OF THE MOTION OF CLOUDS.

It has been already remarked, page 55, that the general body of clouds, according to the observation of Meister, have a progressive movement parallel to each other, and at the same time a rotatory movement, as round an axis. The motion given to particular clouds by the wind, however, differs from these. It's velocity is proportionate to that of the current of air, in which they float, and in stormy weather is astonishingly great. A carriage passing along on a trot at the distance of half a mile can scarcely be observed to move; yet these clouds, notwithstanding their distance, appear to move with great swiftness.

The motion of the higher clouds, too, as they are more remote, is apparently slower than that of the inferiour clouds, though in fact the same. On a windy day, when the Sun shines, and only single clouds fly along, the velocity of the shadow on the ground will astonish you still more, though this flies no swifter than the cloud itself.

The course taken by clouds in different regions of the air is not always the same. While the lower clouds fly swiftly, the higher may stand still, or even move in an opposite direction: for at different heights in the atmosphere different currents of air not unfrequently occur at the same time.

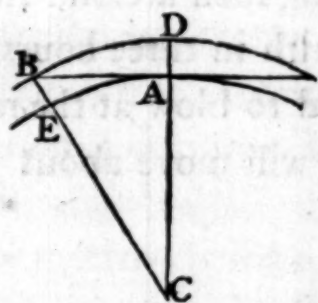
When clouds, coming from the horizon, appear partly to advance straight toward us, partly to take a direction more to the right, and partly more to the left, this is an optical deception. As they proceed toward the eye of the observer in a parallel course, they must appear to diverge, according to the laws of optics, as their apparent distance from each other at the horizon must be less, than when they are over the observer's head: and, for the same reason, these very clouds, when they have passed the observer, must converge in

appearance, as they proceed toward the horizon in the opposite quarter.

“ But,” perhaps some of my more experienced young readers will say, “ it is just the reverse with the stars; for they seem farther apart at the horizon, than in the zenith.” This is very true; but there is one essential difference between the two cases: the distance of the stars is so great, that they are not perceptibly nearer to us in the zenith, than at the horizon; though they *appear* so, because what we see over head seems to us nearer, than what we see at the same distance horizontally; a subject on which I shall enlarge more particularly on a future occasion. Thus, the apparent distance of the stars is in fact the same at the horizon, as in the zenith, but we esteem it greater, because we imagine the stars to be more remote in that situation: with the clouds it is otherwise; they are far more remote from us at the horizon, than when over head, and consequently their apparent distance is actually less.

Suppose we were to inquire how far a cloud, that we see at the horizon, must be from us, estimating it's perpendicular height above the surface of the Earth to be two miles; which

will not be very difficult to such of my readers as are a little acquainted with geometry. We will first draw the following figure.



Let A be the station of the observer; B, the cloud, the perpendicular distance of which from the surface of the earth E A is E B. The semidiameter of the earth, C A, or C E, is pretty nearly 3968 miles; the line B C, therefore, is 3970 miles. The line A B, being a tangent to the circumference, the angle A must be a right angle; so that, according to the celebrated Pythagorean problem, we have only to subtract from the square of the hypotenuse, B C, the square of the side A C, and we shall have the square of A B, the root of which square is the distance sought.

Now the square of the hypotenuse, 3970 miles, is 15760900; from which subtracting 15745024, the square of 3968, we have for

the square of A B 15876; and the root of this is 126, the distance of the cloud from the observer in miles. Now a strong wind is capable of bringing such a cloud from the horizon to the zenith in three hours; for, if we reckon the wind to blow at the rate of 60 feet in a second, it will move about 41 miles in an hour.

CHAP. XVII.

OF WHAT DO CLOUDS CONSIST?

THE substance of clouds is nothing but vapour. At a distance, indeed, a cloud appears to the eye a solid mass; but when, ascending a hill or mountain, we actually come into a cloud, we perceive nothing but a mist around us, sometimes so thick, that we can scarcely see ten yards before us, at other times extremely thin.

The ignorant alone suppose, that the dark blue or brown, or the beautiful red and yellow colours, exist in the clouds themselves;

which is by no means the case. These colours are entirely owing to the refraction and reflection of the sunbeams. When we contemplate the beautiful display of colours exhibited at the rising or setting of the Sun, we might wish to be transformed into aerial beings, to recline on those soft purple and rosy masses, and float with them high above the Earth: but he, who has once passed a day and a night in the clouds, as we did last year on the Brocken, will have no desire to make them his bed. Our friends in Dessau probably were enjoying the sight of the rosy clouds fringed with gold in their western horizon, while we, enveloped in the very clouds they admired, wished them far away, because they prevented us from beholding the setting Sun. Thus we are apt to be mistaken in the value of things we contemplate at a distance, when we do not know what they really are, or neglect to consider their real qualities, and confine our thoughts to these.

Of what, then, do clouds consist? Of very fine *bladders* or *bubbles*, as Saussure's observations confirm; exactly as the steam ascending from a kettle of boiling water, the blad-

ders of which are clearly enough perceptible to a magnifying glass.

But how are these bladders formed? On this the learned are not agreed; and it would afford you little amusement, my young readers, were I to give you their opinions, with the several arguments adduced for and against them. Still you will be glad, probably, of one explanation at least, capable of solving the phenomena, and we will therefore take the following*.

In the first place it is to be observed, that there is a very subtile fluid, which produces heat, or warmth, called the matter of heat.

This matter of heat is capable of combining with the particles of water, or any other fluid, so as to dissolve it; and a fluid thus dissolved in the matter of heat is called vapour.

* The theory here given is that of de Luc, which appears to be the most simple, easiest to be comprehended, and to explain the greater part of the phenomena, at least without violence. The theories of le Roi, Saussure, Hube, and others, are as hypothetical as de Luc's; and the simplest is the best for our purpose, though it may not be perfectly satisfactory. The reader will remember, however, that it is given as conjectural only, not as an explanation unquestionably just.

Vapour, as long as the solution remains perfect, is an invisible elastic fluid. By an elastic fluid is meant a fluid, that has a constant tendency to expand itself, as much as the pressure, to which it is exposed, will allow. The great force of this expansive power is evidently displayed in the steam engine, by means of which astonishing effects have been produced in mechanics.

But the matter of heat has a tendency to leave in part any warm body, and enter into a colder in contact with it, till both are equally warm. Thus when vapour comes into a colder place, a part of the solvent, or matter of heat, is abstracted from it, and something takes place similar to what happens when the fluid in a solution of salt is diminished. In such a case, we know, the particles of the salt unite in a determinate figure, and form crystals: so, when vapour is cooled, the particles of water unite, and form bladders.

Yet why should they assume this particular shape? This we are unable to explain; though it is not more strange, that water on such occasions should always form bladders, than that every salt, when it crystallizes, should assume

it's appropriate figure, of the cause of which we are equally ignorant.

And what is contained in these bladders? That we cannot tell with any certainty. It must be a subtile elastic fluid, however, and of less specific gravity than the air, as it enables the particles of water to float in it. Perhaps it may be still the matter of heat, or the electric fluid.

Vapour may be condensed by pressure also, as well as by the abstraction of the matter of heat, when the pressure is carried to a certain degree. Thus we may compress aqueous vapour to a certain point, without the particles of water attracting each other, so as to become actual water: but if the pressure be carried beyond this, the particles of water will be brought so near together, that their attractive power will overcome the expansive power of the matter of heat, and the vapour will be in part decomposed.

When vapour is condensed into little bladders of this kind, it becomes visible, and not before: and a collection of such bladders, produced by the vapours ascending into the atmosphere, form what we call mists and clouds. When they rest on the Earth, so that we our-

selves may walk in them, we call them mists, or fogs: when they float in the air over our heads, we call them clouds.

CHAP. XVIII.

GREEN AND SHINING CLOUDS.

To finish the subject of clouds, we will add an account of some remarkable for their colour, form, or something else singular in their appearance.

In some parts of the world a particular cloud occasionally appears, to which the german mariners give the name of *hare*, on account of it's swiftness, and which indicates the sudden approach of a heavy gale. A traveller informs us, that, being at sea, he heard one of the crew call out, "here comes a hare," and immediately all hands were set at work, to take in the sails, and prepare the ship for a storm. As he neither found the wind blow, nor perceived any thing, that seemed to forebode a gale, he was surpris'd at the bustle, and inquired into the reason of it. On this, a little

black cloud, low in the horizon, was pointed out to him, which seemed far off, and in which he could discern no tokens of danger. But this small cloud enlarged visibly, approached with astonishing swiftness, and scarcely were the sails furled, before the cloud and the storm arrived together.

The clouds, that hang on the peaks of many mountains, forebode wind and storms; as on Mount Pilate in Switzerland, which derives it's name, *Mons Pileatus*, from it's head being capped with clouds.

At the rising and setting of the Sun, it is usual for the clouds to appear of various colours, but a green cloud is a very rare occurrence, though such may sometimes be seen. Frazer once saw a green cloud at sunset in the torrid zone, and recorded it, on account of it's singularity. "Between the tropics," says Forster, "the morning and evening Sun frequently paints the Heavens with brighter hues, and the mixture of colours is more striking and conspicuous." In the year 1774, on the second of April, in the latitude of 9° 30' south, J. R. Forster observed at sunset a very beautiful green cloud, at a little distance from it were clouds of an olive tint,

and even the sky itself had a lively tinge of light green. The younger Forster observes on this occasion, that he had remarked the same phenomenon at Cassel, in Germany, with all imaginable splendour of colour.

To these observations perhaps many of my readers can add some of their own. Thus in the middle of February last, after a clear frosty day, the sky was uncommonly beautiful here at sunset and just after. Light violet clouds floated in the deep blue zenith; nearer the horizon were rosy red and flame-coloured clouds; and at the horizon in the south west the silvery moon shone from a sky gleaming with the most beautiful transparent green.

Instances of shining clouds too have been known. Thus abbé Rozier relates an observation of a cloud, that emitted light from being surcharged with electricity, at Beaufejour, near Beziers, on the 15th of August, 1781. The day had been very sultry, and a thunderstorm was expected. The sky overhead had been loaded all day with dense, white clouds, and the Sun set behind a vast body of such clouds towering one over another. At seven o'clock in the evening the

atmosphere grew still more loaded with vapour; the great clouds sunk lower in it; and the air became very thick and heavy, so as to render breathing less free. As night approached, the clouds heaped together more and more, and advanced nearer to the chain of mountains, that divides Lower Languedoc from east to west. At a quarter after seven a faint gleaming was observed in the west, from which it might be inferred, that it was thundering at a distance in that quarter. The lightning soon increased, and the thunder began to be audible. At eight o'clock the wind blew from various quarters, driving the clouds in different directions, though the westerly wind still maintained the superiority. The thunder grew more violent toward the mountains, and the whole sky appeared in a blaze. Night now came, and it was impossible to observe the motion of the clouds any longer, as the vivid lightning so dazzled the eye, that the darkness appeared much greater probably than it was. The storm drove hastily from west to east, and toward the mountains was tremendous. Five minutes after eight it was completely night. "Just at this moment," adds Rozier, "as I

was observing the course and action of the lightning, I perceived, behind the brow of a hill, which bounds the prospect from my house on one side, a luminous point. It was not the light of a distant torch, or of burning wood; for it's colour was too white, resembling that of phosphorus burning in the open air, or the electric light of an exhausted glass tube. This luminous point spread more and more, and at length formed a stripe, appearing to the eye about three feet broad*. Over this stripe presently appeared a second of equal breadth, but only half so long, as it's extent was not above 30° . The space between these two stripes, which was about the same breadth with them, remained perfectly dark. These stripes had a horizontal direction, but their edges were not accurately defined, inequalities being clearly observable in them, as in those large white clouds, which forebode a thunderstorm. The edges too were not illumined with equal

* These are Mr. Rozier's words; but the expression is much too vague for a natural philosopher, who should estimate the magnitudes of appearances in the Heavens by the degrees and minutes of the angle they subtend from the observer's eye.

vividness, though the middle of the stripes displayed an equally diffused light. While these stripes moved on to the east, the lightning followed flash after flash. At three different times a flash of lightning issued from the end of the lower stripe; but it was very remarkable, that no thunder was heard after these flashes; though the claps from the more distant clouds, which appeared over the stripes, were very tremendous. Every flash, that issued from the thundercloud itself, enabled me to see the whole country, so that I was more capable of forming a just idea of the two luminous stripes. These stripes continued to be seen from five till seventeen minutes after eight, when a squall of wind from the south altered the direction of the clouds, drove them nearer to the mountains, and carried the storm away from Beziers.

“It may be presumed, that these stripes were collections of electric vapour, rendered luminous by being much condensed. The strongest proof of this is, that the three flashes of lightning from one of them were double the diameter of those, which issued from the thundercloud itself; though in estimating this diameter there may have been

some degree of optical deception from the nearness of the object. The stripes too were distinct from the cloud, because the mountains could be seen behind them, and no thunder followed their lightning."

A somewhat similar appearance was seen between Gotha and Erfort, on the 10th of January, 1782. About midnight, the sky being clear, except a few straggling clouds, several small streaks of fire ascended from the ground at different times, about half a mile from the observers, which were at first taken for skyrockets. But as no sound was heard, as they were not seen to burst, and as it was perceived, that their course was from the ground to the clouds passing over, in which they diffused themselves, even illuminating them internally, they were concluded to be the effect of natural electricity.

CHAP. XIX.

CLOUDS OF SINGULAR SHAPES.



CLOUDS, and clusters of clouds, of singular shapes may be seen frequently, particularly in stormy weather; but sometimes such as are peculiarly remarkable appear. The two following may be taken as instances.

On a clear but sultry summer's day, about three in the afternoon, a distinct dense thundercloud was formed, in the neighbourhood of Gotha, not unlike a mushroom in shape, the head of which appeared like rocks towering over one another. The grandeur of this

vast mass floating under the blue sky attracted my attention. From the slender part, which represented the stem, a very thin and bright vapour was emitted, which in a few moments formed a perfect ring round this part of the cloud. This ring appeared to be in violent motion, by which it was spread more and more, till in the space of a minute it extended beyond the circumference of the upper part. It now began to spread upward and downward, and in less than thirty seconds the whole cloud was enveloped with a transparent covering. This appearance did not continue quite a minute, before the cloud began to spread, as from a wind arising in its centre, and assume the shape of a fan; when it soon lost its smooth edges, which divided into filaments, and acquired the exact appearance of a thundercloud. After a few minutes a black watery cloud arose under it, formed of the vapour that had been driven downward, and the remains of the covering. Every moment I expected the first flash of lightning, which came in a few minutes. A little rain fell at a distance; but within a quarter of an hour the cloud was so diffused

abroad, that it was presently lost in a thin mist.

Mr. Lichtenberg, who gives the above account, says, that he has since observed a similar appearance, though not so striking, in other thunderclouds. Sometimes, too, he has seen it reversed; and, instead of a finer vapour being emitted, and forming a covering to the cloud, the thin white wrack, that has been floating over the thundercloud, has sunk down, spread over it like a veil, and united with it.

That the vapour, in the instance above related, formed a ring round the cloud, arose from it's form. Being repelled by the cloud above and below, it could only distend itself laterally, till it got beyond the limits of the cloud, when it diffused itself upward and downward. If this appearance be compared with the electrical experiment, in which a ball of cotton is suspended by a silken thread in a cylindrical vessel of metal of a proper size, and the vessel is alternately electrified, and deprived of it's electricity, perhaps we may reasonably infer, that it is not very difficult to obtain information concerning the electrical state of the higher regions of the air, and

of the clouds themselves, by paying more attention to the phenomena that occur in them.

One afternoon, toward the end of March, a thunderstorm arose from the west. When the horizon in this quarter had again cleared up, and the storm was gone by, I went into the fields, to enjoy the agreeable prospect, which both Earth and sky commonly exhibit after a thunderstorm. Dark brown and leaden-coloured clouds still floated slowly and heavily over head toward the east in grotesque figures. In the clear western horizon the Sun, now near it's setting, shone forth; and it's beams painted one side of the clouds with a strong yellow light, which formed a striking contrast with the deep shades of the rest. Among all these ragged clouds of singular shape, which gradually passed along, driven by a moderate wind, one particularly attracted my notice. It had a striking resemblance to an immense canopy, or expanded umbrella; and the effect was heightened, by it's appearing, from the point whence I viewed it, to be spread directly over the town. The oblique position of the Sun gave the lights and shades so strongly, that the figure could be dis-

tinguished to great advantage. The inferiour surface, which in most clouds is convex, was a conical cavity, the edges of which were sharp and regular. The superiour surface was more irregular, not unaptly resembling a plume of yellow feathers on the huge cap. This fine spectacle continued in all it's splendour near five minutes, when the wind disordered first the upper part of the cloud, then the under; presently after which it began to rain, and the appearance gradually vanished.

CHAP. XX.

SOMETHING MORE ON THE SUBJECT OF TOADS.

IN the preceding volume it was seen, that the toad may justly be ranked among harmless animals; yet it is not improbable, that it may occasionally prove injurious to creatures that devour it, as seems to have been the case in the following instances.

A healthy, lively dog, running about the garden with his master in the summer of

1794, found a toad of the common species, with warts on the back, and red eyes. The dog fell upon the toad, tore it to pieces, swallowed it, and almost immediately his lower jaw was convulsed, opening and shutting with a quick spasmodic motion. At the same time he foamed at the mouth, and this continued near a quarter of an hour. From this period the dog became dull, and in the evening refused his food. The next day he would neither eat nor drink; and, his state thus becoming suspicious, he was chained up. On the third day it appeared, that this precaution was not unnecessary, for evident symptoms of madness came on; and as these increased on the fourth day, he was killed.

In the dogdays of the following year, the same gentleman met with a similar instance. Walking in the fields after a shower, the dog of a friend in company with him found a toad, and tore it to pieces, but did not swallow it. The lower jaw of the dog became immediately convulsed; white, frothy spittle flowed from his mouth; and this had scarcely ceased before he vomited up a considerable quantity of white, frothy slime, and appeared

perfectly dull and shy. Some medicines were administered to this dog, and he did not become mad: which, however, may have been prevented by his vomiting so soon after, and his not having swallowed the toad.

Possibly the toad may be noxious only at certain seasons, or on being irritated by extreme pain; and under these circumstances it's juices, at least if swallowed, may be capable of producing that horrible disorder, hydrophobia.

CHAP. XXI.

AN EXPERIMENT WITH A GLASS OF WATER.

WILLIAM had heard of turning a glass of water upside down, without spilling any of it, and requested his father to show him how it was to be done.

Accordingly Mr. Goodwin took a glass of water, put a piece of paper over it, and then inverted the glass, pressing the paper close to the mouth of the glass with his hand, and

holding it so, till the water remained still in it's new position. He then took his hand cautiously away; the paper remained fixed to the glass, and the water in it.

"Ah, the paper ——" William began: but he presently reflected, that the paper was not a fixed covering, and that it was as singular for the paper to adhere to the glass, as for the water to remain in it.

Father. "Well, William, how is it? The whole weight of the water presses on the paper, and yet neither of them falls to the ground."

William. "I do not know."

F. "There is nothing above, that holds the water; for the cohesion of the water, and it's adhesion to the glass, are not sufficient, to keep such a weight suspended: something beneath, therefore, must press against the paper; and this can be nothing but the air, for you see there is nothing else under it. Thus it must be the *pressure of the air*, that keeps the water suspended in the glass."

"The pressure of the air!"—said William, reflecting on it, for it did not appear to him clear, how any thing could press from below upward.

F. "I must instruct you a little more in the properties of the air, otherwise you will not be able to understand the phenomenon.

"The air is a thin substance, that surrounds the whole Earth. We cannot see it indeed, but it's effects are visible. The leaves and branches of trees are moved, without any thing being seen to touch them: so the vanes of a windmill are driven round, and a ship with spread sails is impelled along. The wind, that effects all this, is nothing but the invisible substance, which we term air, set in motion. If you move a fan, a piece of paper, or the like, backward and forward, you feel, that something resists it: you feel the impulse of this invisible substance against your face, against your hand: you hear a whistling or rustling noise, when you move a stick or a twig quickly up and down in it. I need not mention more of these known experiments, which will convince you of the existence of a substance, that the eye cannot discern, even if assisted by the best magnifying glasses. This substance, which surrounds us on all sides, is distinguished from other aeriform substances by the name of *atmospherical* air. The first of it's qualities, which I shall notice,

is *fluidity*. You know, I believe, in what this consists, or how fluids differ from solids."

W. "In solids all the particles cohere so strongly together, that the body has a determinate figure; and this figure cannot be changed, or parts separated from it, without force. In fluids the cohesion of their particles is so slight, that these particles easily move about among each other, and take the form of any vessel, into which they are put."

F. "This quality the air possesses in common with other fluids, with water for example. Its particles may be separated with ease, for it is done at every motion we make: yet the resistance of the air is very perceptible, when a body is moved in it swiftly, or has a great surface perpendicular to the line of motion. Many of my readers, no doubt, have heard of a striking instance of this, in the descent of Mr. Arnold from a great height in the air by means of a parachute. This was a machine in the shape of the head of an umbrella, but very large. From it a car was suspended, in which Mr. Arnold sat. Being fastened under the car of an air-balloon, it was carried up with it to a considerable height,

and then let loose. The resistance of the air to this machine was so great, that it descended slowly to the ground, on which Mr. Arnold alighted in perfect safety.

“ The second quality, which air possesses in common with other fluids, is *gravity*. The air may be almost all pumped out of a hollow vessel by means of an airpump, and it will then be found to weigh less, than when it was full of air.”

W. “ Yet, when I hold my hand open in the air, I do not feel, that there is any weight upon it.”

F. “ True: and in the same manner you do not feel any weight upon your hand, if you hold it open in water; for the surrounding water supports the column that is over your hand, by the pressure that it exerts upward, as was noticed on a former occasion. If we could take away the surrounding air, and merely leave the column, that is over your hand, you would not be able to support it.”

W. “ How much then does the air weigh?”

F. A cubic foot of atmospheric air weighs only an ounce and a quarter avoirdupoise: yet the pressure, which the air exerts upon a given surface, is very great. We will endeavour to form an estimate of it: but first we will

notice a third remarkable quality of air, *it's elasticity*.

“We find in air a tendency to expand itself. Thus, for example, if you stop the opening of a syringe, and push in the piston some way, if the piston be tight enough to compress the air within, as soon as your hand is removed from the piston, the compressed air will expand itself, and push the piston back. Many more proofs of this elasticity are seen in experiments with the airpump, with which you will hereafter become acquainted. For instance, if you tie a bladder tight, that has but little air in it, place it under the receiver of an airpump, and pump the air out of the receiver, the bladder will swell up; the little air contained in it expanding, as soon as the pressure of the external air is diminished.”

CHAP. XXII.

HOW GREAT IS THE PRESSURE OF THE AIR?

“We will now endeavour,” said Mr. Goodwin, “to ascertain the pressure of the air.”

On this he took a glass tube, about the size of a large quill, thirty inches long, and close at one end. Holding the closed end downward, he filled the tube with quicksilver, put his finger over the open end, inverted the tube, held it over a cup with the open end downward, and withdrew his finger. Some of the quicksilver now ran out, and left an empty space or vacuum, at the upper end: but this was not more than two inches in length, the other twenty eight inches remaining full of quicksilver.

“Do you know the purpose of this experiment?” said he to his son.

W. “We wanted to know the pressure of the air; and by this we see, it is sufficient to support a column of quicksilver 28 inches high.”

F. “As quicksilver is fourteen times as heavy as water, how high a column of water would the air support?”

W. “The column of water would be fourteen times as high, that is, 14 times 28 inches, which make 392 inches, or 32 feet eight inches.”

F. “Now you may imagine, that, as I told you before, you could not support the

column of air, that presses upon your hand, if the surrounding air were removed."

W. " Yes : but there are two things, that are not very clear to me."

F. " What are they ?"

W. " Why is it, that, in the experiment with the glass, the water would not remain in it, when the paper was taken away ? The pressure of the air was not removed."

F. " The reason is, the lower surface of the water does not remain perfectly at rest in a horizontal position, so that the pressure is not every where equal and uniform, and in consequence the air, being the lighter fluid, ascends, while the water descends. In a slender tube like this, when inverted, the cohesion between the particles of water at so small an aperture would be sufficient, to preserve a smooth surface, without any paper, so that the air beneath would press uniformly against it, and support it."

W. " I have still another difficulty. We are here in a room, which has a ceiling over head. The air over this ceiling cannot press upon any thing in the room: the pressure of the air out of doors, therefore, ought to be

much greater than within; yet I find no difference."

F. " You must consider, the air is fluid and elastic. The air without doors is pressed upon by the air above it: but as fluids press equally every way, the pressure on the air without is communicated to the air within, through the door, windows, and chimney, so that both are equally compressed, and consequently the pressure they exert upon objects is equal.

" Let us now calculate with how many pounds weight the air presses upon this table, for instance. How must we set about it?"

IV. " We must first measure the surface of the table, and then calculate the weight of a column of water of the same dimensions and thirty two feet eight inches high."

William measured the table, and found it to be three feet long, and two feet broad. The surface therefore was six square feet. Multiplying the height of the column by this gave a product of 196 cubic feet; and this multiplied by 62 pounds and half, the weight of a cubic foot of water, gave 12250 pounds.

F. " Hence you may infer the greatness of the force, with which our bodies are con-

tinually pressed on all sides. Had they not equally elastic air within them, which counterbalances the enormous weight, we must certainly be crushed to death. On the contrary, were the pressure of the circumambient air removed, the air within us would burst our bodies by its expansion."

CHAP. XXIII.

OF THE BAROMETER.

WILLIAM had frequently seen his father looking at a barometer, and raising or lowering an index at the upper end, but he did not understand the use of the instrument, or what was in fact to be observed in it. The experiment with the glass tube in the last chapter now led him to conjecture, that it must relate to the pressure of the air, and this he mentioned to his father.

"You have guessed right," said Mr. Goodwin: "here, examine the instrument a little more closely. You perceive, it is nothing more than a glass tube, close at top, bent

round and open below, and nearly full of quicksilver. This quicksilver is supported in the tube by the pressure of the air, which acts only on the surface of the quicksilver in the short open leg, as the space above the quicksilver in the closed end of the tube is a perfect vacuum: for, when the barometer was made, it was completely filled with quicksilver, which sunk down by its own weight, when the tube was inverted, as you saw yesterday; so that no air could have gotten into this space, unless it had been admitted purposely. In a good barometer, shaking the tube will produce an audible sound from the quicksilver at the top; but this will not occur, if there be air over it.

“ The purpose of this instrument you will understand yourself: it serves to measure the pressure of the air. For instance: the quicksilver now stands at the height of 28 inches in the tube; what does this prove?”

W. “ That the pressure of the air on the surface is equal to the pressure of a column of quicksilver 28 inches high.”

F. “ But, when the quicksilver rises in the tube?”

W. “ The pressure of the air must be great-

er; and, on the contrary, when it falls, the pressure must be less. This is clear: but why is the lower end round like a ball?"

F. "The reason is this. A mere straight tube, open at the end toward the ground, would not answer the purpose: for, not to mention the ease with which some of the quicksilver would be thrown out whenever it was moved, some must be lost when the quicksilver descended from the diminution of the pressure, and the remainder would not be sufficient to balance the increased pressure of the air. The lower end, therefore, must either be placed in a vessel to hold the quicksilver, or bent round, which, you must be aware, is the most commodious.

"Still there is something more to be considered. When the quicksilver falls in the longer leg, it rises in the shorter: and the contrary. Now, if the shorter leg be wide compared with the longer, it will rise in it but a little way, while it falls considerably in the other. The height of the column of quicksilver, supported by the air, must be reckoned from a horizontal line drawn level with the surface of the quicksilver in the shorter leg; for all the quicksilver below this line in the

longer leg is counterpoised according to the laws of hydrostatics by the quicksilver in the shorter. Now, if the height of the quicksilver in the shorter leg be very little altered, which is the case when it is of considerable width, as I observed before, no great error arises from the measuring the height of the column supported by the pressure of the air in all cases from a fixed point. This is the reason why the common barometer has a ball at the lower end.

“ Still it would be more accurate, to leave the barometer tube of equal size throughout, and observe the rise and fall in both legs. In this case, if the quicksilver fell one line in the longer leg, it must rise one line in the shorter, and consequently the column of quicksilver supported by the air would be two lines shorter than before.”

W. “ Why, then, do people call this instrument a weather glass ?”

F. “ It has some claim to the name, because fine and settled weather generally follows the rising of the quicksilver; and when it falls, variable, stormy, or wet weather commonly ensues. The reason of this, however, I can-

not well explain to you ; indeed we do not know the causes of it with any certainty.

“ What the barometer properly shows is an increase of the elasticity of the air when it rises, and a diminution of the elasticity of the air when it falls. Now, aqueous vapour, while it exists in an undecomposed state, is very elastic, and perfectly transparent : whence it increases the elasticity of the air, and leaves it clear. The rise of the barometer, therefore, may be considered as an indication, that probably the elasticity of the air is increased by aqueous vapour in a state of perfect solution, and that the weather will be on this account fine. On the other hand, if the quicksilver fall, it may be presumed, that the vapour, before perfectly mixed with the air, is decomposed, by which the elasticity of the air is diminished ; and that rain, or changeable weather, may in consequence be expected. We must not flatter ourselves, however, as I said before, that this is a perfect explanation of the phenomena.”

CHAP. XXIV.

THE THERMOMETER.

IV. "WHAT is the use of this little glass tube by the side of the greater?"

F. "The little tube is a *thermometer*, that is, an instrument for measuring the warmth of the air, or any thing else that surrounds it.

"It is a well known fact, which you yourself have often experienced, that heat enlarges bodies, and cold diminishes them. An iron ball, which will just pass through a hole when cold, will not go into it when heated. An iron rod is perceptibly longer when hot, than it is when cold. This effect of heat is the principle, on which the thermometer is constructed. The ball, and part of the tube, are filled with quicksilver, or with pure spirit of wine tinged red: if either of these fluids be exposed to heat, it expands, and consequently rises higher in the tube; when it is cooled, it sinks. Spirit of wine, however, is

much inferiour to quicksilver for the purpose, and now seldom used.

“ By the side of the tube is a scale, and on it is marked the height, to which the fluid rises at different degrees of heat. Two principal points in it are first ascertained: that at which water freezes, and that at which water boils. The interval between these two points is divided into a certain number of equal parts, or degrees. Natural philosophers, however, have differed in their divisions, whence we have thermometers with different scales.

“ The principal are Fahrenheit's, which is used in England; Reaumur's, as it is called, heretofore used in France; Celsius's, or the Swedish; and del'Isle's, or the Russian. The distance between the point at which water freezes, and that at which it boils, is divided into 180 degrees in Fahrenheit's scale, 80 in Reaumur's, 100 in Celsius's, and 150 in de l'Isle's. Reaumur and Celsius began their scale from the freezing point, expressing this by 0: Fahrenheit began his 32° below the freezing point, making that of boiling water 212° : and de l'Isle began his at the boiling point, from which he reckoned the degrees downward. It is to be observed, that the thermometer

invented by Reaumur was made with spirit of wine, and it's scale does not agree exactly, though it does nominally, with that which now goes by his name, though in fact invented by Mr. de Luc. The thermometer commonly called Reaumur's, therefore, ought in strict propriety to be called de Luc's. This and Fahrenheit's were the most common, but now that with the decimal division, or Celsius's, is generally used in France.

" Every thermometer must have it's scale adjusted to itself, for the quicksilver will rise or fall through a greater or less space, with the same degree of heat, according to the size of the ball, and the diameter of the tube."

W. " Is not the ball unnecessary ? for the quicksilver, or spirit, would expand with heat, and contract with cold, if there were only a tube partly filled with it."

F. " We might do without the ball, it is true; but it would be very inconvenient: for, if we would mark slight changes in temperature, we must have the tube very long in this case. Thus, for example, suppose a change in temperature, that should expand the quicksilver a thousandth part of it's solid contents: if the column of quicksilver were ten inches, or 100 lines, long, and the tube

a quarter of a line square, the solid contents of the column of quicksilver would be 25 cubic lines, and the expansion would be $\frac{325}{1000}$, or $\frac{1}{3}$, of a cubic line. But, the tube being $\frac{1}{4}$ of a line square, the quicksilver would rise only $\frac{1}{16}$ of a line, which would be a length not easily observed.

“ Now, if to a tube of this size we add a ball containing half a cubic inch, or 500 cubic lines, we shall have a much larger body of quicksilver, with the same length of tube: for, these 500 cubic lines of quicksilver being added to the 25 in the tube, we shall have in the whole 525 cubic lines, the expansion of which, with an equal degree of heat, will be $\frac{525 \times 325}{1000}$ of a cubic line; and consequently the quicksilver must rise two lines and $\frac{1}{16}$ in the tube, to fill this space.”

William did not immediately understand how this was found: his father, therefore, explained it to him.

F. “ As the solid contents of the quicksilver are 525 cubic lines, an increase of a thousandth part must be $\frac{525}{1000}$ of a cubic line. If the transverse section of the column were exactly a square line, the addition of $\frac{525}{1000}$ of a line to it's height would give $\frac{525}{1000}$

of a cubic line: but, as it's transverse section is only $\frac{1}{4}$ of a line, it requires of course four times as much additional height. If, therefore, we multiply $\frac{1}{16}$ by 4, we shall have $\frac{4}{16} = \frac{1}{4} = 2\frac{1}{8}$.

“ This is a length, which may be observed with ease: and if we have the thermometer with a ball of tolerable size proportioned to it's tube, we may conveniently observe with it all degrees of heat, not exceeding that of boiling water, though the tube do not exceed a foot in length. To measure higher degrees of heat, that at which quicksilver boils, for example, which is 600 of Fahrenheit, we must have longer tubes it is true: but from what has been said it is clear, that a tube without a ball, capable of showing tolerably small changes of temperature, must be of such a length, as to be extremely inconvenient.”

CHAP. XXV.

MAGICAL FOUNTAINS, MAGICAL CUPS,
&c.

As William went into his father's study the next day, he saw the table covered with various instruments, with which he was unacquainted.

"I believe," said his father, "I can show you some very amusing experiments, effected by means of the pressure of the air."

William was all attention.

F. "This (fig. 4.) is called a taster, and is used for taking wine or any other liquor out of a cask. Being put into the bung-hole, the liquor flows into it, till it is on a level with the rest: the hole at the top is then stopped by putting the thumb over it, and the taster being lifted up, the pressure of the air against the small aperture at bottom prevents the liquor from running out. You may then suffer it to run into a glass at pleasure, by removing your thumb, so as to allow the air to press upon the upper surface

as well as the lower ; and may stop the issue of the liquor when you think proper, by replacing your thumb on the upper orifice.

“ This (fig. 5) is called a *magical fountain*, or *fountain at command*. It is thus constructed. The pillar (a), on which the upper vessel (B) rests, is hollow, and reaches above the surface of the water in the reservoir (B), which is covered close. Near the bottom, which is in the basin (C), there is a hole on one side; and as long as the external air can have access to this hole, it rises through the pillar into the reservoir (B), the water in which consequently flows out through the two small pipes (D, E) into the basin below. The basin is thus gradually filled, till the water gets above the opening in the bottom of the pillar, and shuts out the air; on which the water ceases to flow. In the bottom of the basin (C) however there is a hole, less than those in the upper reservoir (D, E), so that it could not discharge the water from the basin so fast as it ran into it, but through which the basin now empties itself into the lower reservoir (F). When the water thus gets below the opening at the bottom of the pillar, the air has again access to the upper

reservoir, and the two fountains begin to flow afresh. Thus they go on alternately flowing and stopping; and, if you attend to the hole in the pillar, you will know when it will flow, when not, and consequently may appear to order it to stop, or to flow. If the hole at the bottom of the pillar, instead of opening into the basin, were connected with the outside of it by means of a tube, as in some of the contrivances to be mentioned presently, the orifice of which could be stopped at pleasure, you might really cause the fountains to flow or cease at will.

“ This (fig. 6) is a magical cask. Turn the cock: you find nothing runs out. Now shut the cock, take out the bung, and with this funnel pour water into the bunghole.”

William did so.

F. “ Take this glass, hold it under the cock, and turn the cock once more.”

To William’s great astonishment, he found his glass now filled with wine.

F. “ Can you account for this?”

W. “ No.”

F. “ I will explain it to you. The cask is divided within by a partition, which is close at the bottom and sides, but admits a

communication between the two parts near the top. The cock opens into one part ; the bung into the other. I had previously put wine into that part, where the cock is ; but the aperture of the cock being small, and the bung being so tight, as to exclude the external air, it would not run out, when the cock was turned. The water, being poured into the other part, remained separate from the wine ; but it compressed the air over the wine, so as to cause the wine to run out, when you turned the cock again.

“ This compressed jet d'eau (fig. 7.) is commonly called a *Heron's ball* in Germany. The glass ball being about half filled with water, you blow air in through the tube, which reaches almost to the bottom. The air, thus compressed over the water, strives to expand itself as soon as the force is removed, and thus drives the water out of the tube, the aperture of which being very small, it rises in a jet. As the air within dilates, the water is driven out with less and less force, till the density of the air within is reduced to an equality with the density of the external air. By blowing air in again in the same manner, you may make the foun-

tain play afresh, till the water is too low in the ball. To fill the ball, you must proceed in an opposite manner; sucking the air out, and preventing the admission of fresh air by turning the cock in the neck, till the end is plunged into a vessel of water, when, the cock being turned again, the pressure of the external air on the surface of the water will force it into the tube. If the ball and tube were made of copper, and strong, and a good syringe fitted to it so as to be air-tight, the air in it might be condensed to a great degree, by forcing it in with the syringe, or by forcing in the water upon the air with this instrument."

A similar fountain to this William contrived to make himself, by fixing a slender stem of a tobacco-pipe in a strong phial, so as to be air-tight, with sealing wax.

F. " In the circulating or Heron's fountain (fig. 8.) the water is driven out in the same way as in the magical cask. Two of the pillars, that support the upper reservoir, are hollow. One (D) reaches from the bottom of the basin (A) into the lower reservoir (C); the other (E), from the lower re-

servoir (C) to the upper (B), in which it opens near the top, so that it's aperture is above the surface of the water in the upper reservoir. In the centre of this upper reservoir is a tube (F), reaching almost to it's bottom, and opening with a very small hole at top, through which the jet rises. As long as the basin (A) is empty, there is no appearance of any jet; but the basin being filled with water, it descends through the hollow pillar (D) into the lower reservoir (C), drives the air out of this reservoir through the other hollow pillar (E) into the upper, where it presses on the surface of the water, and forces it out through the tube (F) in a jet. The water of the jet, falling back into the basin, descends from it into the lower reservoir; and consequently the fountain continues playing, till the upper reservoir is emptied."

CHAP. XXVI.

SIPHONS, AND TANTALUS'S CUP.

F. "THIS curved tube (fig. 9.) is a *siphon*. Fill it with water, and then put the shorter leg into this tumbler."

William had no sooner done it, but the water began to run out of the longer leg; and, to his astonishment, continued, till the tumbler was nearly emptied of the water previously contained in it.

F. "What, do you suppose, is the reason of this?"

W. "It appears as if the water in the outer leg of the siphon, as it ran out, drew that in the other leg, and in the glass, after it."

F. "You have just the same idea of it, as many others before you have had, some of whom might have been presumed capable of judging better. The cohesion of water is far too weak, to produce such an effect; which would be, as an intelligent man once wittily observed, the same thing as making

a rope of water. There must be some other cause, therefore: and this is nothing but the pressure of the air, and the unequal resistance of the two columns of water, which, it is to be observed, must be unequal, from the inequality in the length of the two legs. The pressure of the air against the water in each leg is to be considered as the same; since the apertures of both are equal, and the little depth to which the shorter is immersed in water does not make any perceptible difference. But the height of the columns of water in the two legs not being the same, they do not resist the pressure of the air equally, and consequently are not in equilibrium.

“ Suppose the length of the longer leg to be 60 lines, that of the shorter 55. If one leg only were filled with water, the air would press equally on each end of the column, and the water would run out by its own weight, as from a tube open at both ends; but, when both legs are full, the air is prevented from pressing upon the top of either column, by the weight of the water in the other. Hence, as the pressure of the air upon the top of the shorter column is

resisted by a column of 60 lines of water, while that upon the top of the longer column is resisted by a column of water of 55 lines only; the water in the longer leg must be pressed downward with a force equal to that of a column of water of 5 lines, in addition to that which counterbalances the pressure upward. Consequently the water will begin to flow out of the longer leg; and, as it flows, the water must be impelled up the shorter leg by the pressure of the external air, which then will have nothing to overcome but the weight of the water in that leg. Thus the water will continue to flow out of the longer leg, and up the shorter; till, the surface of the water in the vessel being reduced below the opening of the shorter leg, the air enters into it, and empties the siphon."

On the table stood a pewter goblet with a cover (fig. 10). William had been desired to fill it nearly with water, before his attention was called to the siphon, and he had done so. On uncovering the vessel, the water still remained in it, and his father desired him to fill it now to the brim. This was scarcely done, when he perceived the

quantity diminish; and it continued decreasing, till the goblet was empty; the water having entirely vanished, without there being the least appearance of it on the table, or any where else. The goblet being filled again, remained full. Mr. Goodwin then poured out the water: a third time it was filled; and it emptied itself as before.

F. “A similar exhibition by professed jugglers has often excited no small degree of surprise and wonder in a numerous company; but you, I presume, can guess at the principle on which it is founded. You will readily suppose, that there is a siphon concealed in the goblet. The sides of it, in fact, are double; and there is a siphon between them, the shorter leg of which opens at the bottom of the part into which the water is poured, the longer into the foot, which is hollow, and equal in capacity to the cup part. In the upper part of the stem are holes, that the air may have free issue from the bottom. As the siphon reaches nearly to the top of the vessel, and is at first empty, the water, when poured in, rises as high in it, as in the vessel itself, but no higher. As long, therefore, as the surface of the water is

below the top of the siphon, it remains in the vessel : but as soon as the vessel is filled higher than the top of the siphon, water passes over into the longer leg, the siphon begins to act, and thus the water is gradually emptied into the hollow foot. The foot being filled, the siphon cannot act, when the vessel is filled again: but the foot being emptied through the holes in the upper part, when the water is poured out, the siphon is again capable of acting as before. This cup has been made with a figure of a man in the centre, and a siphon concealed in the figure of such a height, that, just before the water reaches the mouth of the man, the siphon acts, and empties the vessel. Hence it has derived the name of Tantalus's cup."

CHAP. XXVII.

THE OBSEQUIOUS DIVER.

AMONG the rest of the articles on the table William observed a glass jar, nearly

filled with water, containing the figure of a man in enamel floating in it, and the mouth covered with a piece of bladder tied on it. His father, placing his fingers over the mouth of the glass, commanded the figure to descend, to rise again, quickly or slowly, and was punctually obeyed; the little figure turning round sometimes as swiftly too, as if he had been impelled by the vortices of the inventor of the experiment, des Cartes.

“That is very pretty!” exclaimed William.

F. “Are you not ready with our old question too:—what is the reason of this?”

W. “It must be done by your fingers, which you hold over the glass; for there is nothing else to act upon the figure: but I cannot tell how, and should be glad to know.”

F. “I will inform you. The figure is hollow, of nearly the same specific gravity with water, and has a small hole in one foot.

“When I press down the bladder with my finger, the air, being compressed, forces a little water into the figure. This renders it heavier than the water, and consequently it sinks. The pressure being taken off, by re-

moving my finger, the air, which had been compressed within the figure by the entrance of the water, by it's elasticity forces the water out again, and the figure ascends to the surface. If I press lightly on the bladder, but little water is forced in, and the figure does not sink to the bottom. If I make the pressure gradually, it sinks slowly: if suddenly, it sinks quickly. It is the same with it's rising. The circular motion it has is owing to the hole being on one side: for, when the finger is suddenly raised, the water issuing out quickly is resisted by the water in the vessel, which does not immediately yield to the impulse; and thus it's reaction, being exerted on one foot, turns the figure round. The celebrated Wolf, indeed, explains this rotatory motion in a different manner: but he only shows, that he did not understand it. Which I mention, as the instance of Buffon, on occasion of the animalcula of infusion, to remind you, that you ought to examine every thing for yourself, and not be led away by the authority of a great name."

William now tried the experiment himself; and was not a little pleased, to find how well

he succeeded. When he had amused himself with it as long as he thought proper, he placed the jar in the window, which faced the south-west. The next morning he invited one of his play-fellows, to see him perform the experiment, by which he had been so much entertained: when, to his great disappointment, he found his inanimate diver lying at the bottom of the glass, from which he would no longer rise at his command. He pressed upon the bladder with his finger, and removed the pressure repeatedly, to no purpose. He shook the jar carefully, so as not to break the brittle puppet: but in vain. That water had gotten into the figure, and rendered it too heavy, William readily conjectured; yet he could not account for it. The jar had stood unmoved: both it and the figure were uninjured: the bladder was tied on as tight as ever: and, indeed, no one had been in the room. He went to his father, to know what was to be done.

“ There is no difficulty in remedying it,” said his father, “ we have only to suck the water out of the figure: but how did it get in?”

W. “ That I came to ask you: I have not touched the glass since yesterday.”

F. “ But you let it stand exposed to the Sun, and that was the cause. The heat of the Sun expanded the air within the figure, and consequently forced some of it out, which immediately rose to the surface of the water. As soon as night came on, and it grew cool, the air within the figure was no longer rarefied, but returned to it's former dimensions; and of course water rushed in, to fill the space, which had been occupied by the air, that was expelled. Accordingly the figure was rendered heavier than water, sunk to the bottom, and will not rise, till the water is extracted.”

CHAP. XXVIII.

SOME ENTERTAINING EXPERIMENTS.

How to place a glass of water on the table, so that a person cannot take it up without spilling it.

Put a piece of paper over the mouth of the glass; turn it upside down, as in chapter

XXI; and then place it in this position on the table. When you have done this, holding the glass carefully with one hand, draw away the paper cautiously from under it with the other, and no one can take the glass up, without spilling the water, unless he have the art to reverse the process. This may be done, if you take another piece of dry, smooth paper, tolerably stiff, but not thick, and slide it carefully underneath the glass; you may then lift the glass off the table again.

On the former occasion, in chap. XXI, the general principle only was assigned, the pressure of the air from below upward: for such of our readers, however, as reflect a little deeper on things, we will go a little farther into the subject.

“It is true,” such a one may say, “the air presses from beneath upward; but the space above the water, in the inverted glass, is not a vacuum, as in the torricellian tube*;

* The barometer is so called from its inventor Torricelli. A vacuum, produced in the manner in which that over the quicksilver in the barometer is made, is for the same reason called a torricellian vacuum.

for, when the glass is inverted, the air, which was previously between the water and the paper, is between the surface of the water and the glass. Now has not this air the same degree of elasticity as the external air?—Does it not consequently exert an equal pressure on the water?—And must not the pressure from above and that from below balance each other, therefore, so that the water will fall by it's own weight, as in the open air?"

To this string of questions we reply: "The moment the glass is inverted, the air above the water possesses the same density and elasticity as the external air; and, on this account, a small quantity of water always makes it's appearance between the paper and the brim of the glass, as soon as the hand, that held the paper against the glass, is removed. But with this sinking down of the water the space above it is enlarged; consequently, the air over it, being obliged by it's nature to expand itself through a somewhat larger space, has it's density and elasticity proportionally diminished; for no fresh air can enter in, as it is excluded by the interposition of the paper."

“ But the paper is not fixed to the brim of the glass so as to be air-tight.”

“ If it be not fixed to it, the space between the glass and the paper is closed by the water that descended; and this space is so small, that the air is not able to overcome the attraction of cohesion between the particles of water included in it.”

“ How long, then, does the water continue to descend?”

“ Till the air between the water and the glass is so far dilated, that it's diminished elasticity, added to the weight of the water, is exactly counterpoised by the pressure of the external air.

“ If you hold the inverted glass a little obliquely, you will find, that the water accumulated round the brim by the attraction of cohesion will descend toward the lower part; and that part of the brim which is highest being no longer defended by the external water, the air will press in, and ascend in a small bubble to the top. As every such bubble increases the quantity of air within the glass, a proportionate quantity of water will be found to issue out of it at the lower part of the brim; and this will go on, till the glass

is emptied, unless you restore it to the perpendicular position again. It is the same thing, if you employ a trencher instead of a piece of paper; and with this you will see the water accumulated round the brim more perspicuously."

There is a different mode of setting a glass upon a plate or saucer, so that a person cannot remove the glass without spilling the liquor in it.

Pour a certain quantity of water into a saucer, or soup-plate. Invert a glass over a piece of burning paper, or, which is better, over burning brandy, or spirit of wine; and, after holding it in this manner a short time, set it in the saucer: the water will ascend into the glass, and leave the saucer nearly dry.

To understand this, it must be observed, the air is at first greatly dilated in the glass by the heat of the flame. When the glass is set over the water, this air is cooled, its elasticity diminishes, and the external air presses the water into the glass. Care must be taken, however, that the glass is not made too hot, otherwise it will crack on being suddenly cooled by the water.

Thus, in the operation of cupping, a number of incisions being made through the skin, a hollow glass vessel, called from it's use a cupping-glass, is placed over them, the air in it being previously rarefied in the manner above-mentioned; and as this air condenses by cooling, the pressure of the external air forces the blood through the incisions into the glass.

CHAP. XXIX.

ANOTHER CURIOUS EXPERIMENT.

To raise up a heavy metal mortar, or the like, with a wine glass.

HAVING inverted the mortar, spread on the bottom, or at least where the brim of the glass is to be placed, a little paste of flour and water. Then pour some spirit of wine into a small cup, set it on fire, and hold the glass over it, so that the flame shall ascend into the glass, and heat and dilate the air within it. When you suppose the air to be sufficiently dilated, place the glass without

delay on the paste, and press it tight against the bottom of the mortar, so that no air can press in from without. Let it remain thus, till the air within the glass is cooled; and then, if you lift up the glass, it will raise the mortar with it.

You may use a piece of wet leather instead of the paste: but the paste is better, because the brims of common glasses are not always sufficiently even, to press close to the leather in every part, and a heated glass will be apt to crack, when it comes into contact with wet leather.

William, who was much delighted with the experiments described in this and the preceding chapters, because he saw the principles of them, was desirous of knowing the power, with which the mortar adhered to the glass.

Father. "There are two ways of finding this: by calculation, and by experiment. The following instructions will be sufficient, to enable you, to make the calculation.

"The pressure of the external air, you know, is equal to the weight of a column of water thirty-two feet high, the base of which is of the same dimensions as the mouth of the

glafs. To counteract this preffure there is the weight of the mortar, which may easily be found by a pair of fcales, with the elasticity of the air ftill remaining in the glafs, though this is but trifling."

William now began to weigh, to meafure, and to calculate.

The weight of the mortar he found to be ten pounds and a half.

The diameter of the glafs was two inches and a quarter, or 2.25 inches: from which he calculated the circumference and furface of it's mouth as follows:

	inches.	inches.
If 100	314	7.065
	2.25	
	1570	
	628	
	628	
	100)706.50	
Circumference =	7.065	
	2.25	
	35325	
	14130	
	14130	
	4)15.89625	
Surface =	3.9740625	inches fquare.

Omitting the lower fractions, then,
the base of a column of water 3.97 inches.

Multiplied by the height 32 feet, = 384

$$\begin{array}{r} 1588 \\ 3176 \\ \hline 1191 \end{array}$$

Gives solid contents 1524.48 cubic inch.

But a cubic foot of water weighs 1000 ounces avoirdupois. Therefore

inches. oz. inches. oz. lbs.

If 1728 — 1000 — 1524.48 — 882.22 = 55.14

$$\begin{array}{r} 12 \overline{) 1524480.00} \\ \hline \end{array}$$

$$\begin{array}{r} 12 \overline{) 127040} \\ \hline \end{array}$$

$$\begin{array}{r} 12 \overline{) 10586.66} \\ \hline \end{array}$$

$$16 \overline{) 882.22} (55.13 \text{ lbs}]$$

$$\begin{array}{r} 80 \\ \hline \end{array}$$

$$\begin{array}{r} 82 \\ \hline \end{array}$$

$$\begin{array}{r} 80 \\ \hline \end{array}$$

$$\begin{array}{r} 22 \\ \hline \end{array}$$

$$\begin{array}{r} 16 \\ \hline \end{array}$$

$$\begin{array}{r} 62 \\ \hline \end{array}$$

$$\begin{array}{r} 48 \\ \hline \end{array}$$

$$\begin{array}{r} 14 \end{array}$$

The weight of a column of water, therefore,
the base of which should be equal to the

mouth of the glass, or of a column of air the height of the atmosphere, which is the same thing, would be something more than fifty-five pounds; and with this force would the glass be pressed against the mortar.

Deducting from this the weight of the mortar, $10\frac{1}{2}$ lbs., which the glass would have to raise, the force would still be upwards of forty-four pounds: though less than this would be found on trial to separate them; for the air remaining in the glass would possess a certain degree of elasticity, which must be greater or less, according to the quantity expelled by the heat applied.

CHAP. XXX.

THE ILLUMINATED FOUNTAIN, AND FOUNTAIN OF FIRE.

WILLIAM was highly delighted one evening, when his father sent for him into his study, at seeing on the table a double fountain, spouting up two streams of fire.

It's appearance was that of fig. 11. It consisted of a glass globe, with a hollow stem, from which issued two arms, that bent upward at the end, and terminated with very small apertures. The tube was stopped with a cork, and set in a tin stand, which likewise had two arms, with a small cup at the end of each. The globe was half full of spirit of wine; and spirit of wine was put into the cups, and kindled. The air within the globe, being heated by the flame, was in consequence dilated, and pressed with greater force upon the spirit, causing it to spout out of the aperture in each arm. These apertures being directly over the cups, the spirit was set on fire by the flame, thus forming two jets of liquid fire, which had a very pleasing appearance, in a room where there was no other light.

The illuminated fountain (fig. 12), which his father then showed him, was another worked by means of heated air. It consisted of two tin vessels, one over the other. The uppermost was supported by four pillars; one of which, being hollow, formed a communication between the two. The pillars were about two feet high; the vessels, six inches each, and nine inches in diameter. Beneath the upper vessel were four lamps burning,

one fastened to each pillar. From the centre of the lower vessel rose a tube with a narrowed opening, and furnished with a stop-cock. After the lamps had burned a little while, the cock was turned, and a slender stream of water spouted up, almost as high as the upper vessel.

The lower vessel had been previously filled with water, and then stopped close, so as to have no communication with the external air. The upper vessel was air-tight. Consequently, when the air in the upper vessel was rarefied by the heat, it pressed upon the water in the lower vessel by means of it's communication with it through the hollow pillar, and forced it up out of the tube, as soon as the cock was turned. Then the heat continuing to rarefy the air, the fountain continued playing, till the lamps were extinguished, when it quickly stopped.

CHAP. XXXI.

MICROSCOPICAL AMUSEMENTS.

William to Henry.

DEAR HENRY,

IT is long since I wrote to you, but, to make you amends, I hope I shall now send you something amusing. Yesterday our father entertained us with an exhibition of various things in the microscope. Caroline had complained, that he had shown me so many curious things, which she could not see, because she was busied in the affairs of the house. These, he told her, were objects of most importance to a girl; but, that she might not be altogether without her share, he would exhibit to us both some things, small indeed in themselves, but capable of exciting ideas of ample extent. Accordingly, it being a fine funshiny day, he fixed his solar microscope in the window shutter, and placed another mi-

croscope on the table, for such things as could not be seen so well through the former.

I requested him first to explain to us, how these instruments were made, and why they made things appear so large: but he told me, that I must wait for some other opportunity, and satisfy myself for the present with seeing the exhibition; which indeed afforded me a great deal of entertainment.

Of some of the articles I made drawings, as they appeared, to send to you.

The first object we saw under the microscope was a piece of fine silk crape, about the size of a lentil (fig. 13). Fine as it appeared to the naked eye, it was as coarse under the glass as the figure I have drawn. Caroline stared when she saw the rough black cords, and their ragged appearance on the torn edges of the crape.

The next was a piece of *shot silk*, the warp of which was red, the weft blue, fig. 14. This appeared very regular, and pretty. The threads lay tolerably even and parallel; the fine fibres, of which each thread was composed, were very clearly to be seen; and between the threads were regular square open-

ings, though the filk looked very close to the eye.

Caroline then cut off a bit of a black fatten riband, which looked very dingy, and it's texture obscure.

"You see," said our father, "how coarse these fine and delicate performances of art appear. Now look at an object, which is the work of nature, and you will be astonished, to see how nicely she finishes the minutest parts, which are scarcely visible to the eye assisted by glasses." On this he took the foot of a dead fly, or rather the lower end of the leg, and placed it under the microscope. How were we astonished at seeing it! (fig. 16). There were four joints, and what might properly be called the foot. Each joint was thicker below, than where it was fastened to the other above: each was furnished with hairs or bristles; and at the lower end, where it projected over the next joint, were strong prickles, pointing downward. The foot itself, or the lower end of it, had two balls, covered with extremely slender short hairs, like a fine down, but thicker on the under part than the upper; and at the side of each was a sharp, crooked claw. The fine down,

seen in a certain position toward the light, appeared of a beautiful sky-blue colour: but this, our father said, might be owing merely to the refraction of the rays of light. We looked at this foot when magnified by the solar microscope also, and then it appeared as big as the foot of an eagle.

“ See,” said our father, “ how much more abundant matter for reflection is afforded by the smallest objects of nature, than by the most elaborate performances of man. Consider the slenderness of these hairs, that cover the foot, which are scarcely visible when so greatly magnified. Consider the fineness of the vessels, which there must be in this limb, to supply it with nourishment, as we have arteries in our legs. Consider how curiously it is framed for it’s office. Here are several joints, connected one to the other, and moveable as our leg at the knee, nay capable of more extensive motion. By means of these, the fly springs up with great velocity, when it would take wing. See how providently the foot is furnished with claws, to render it easy for the insect to hold itself securely, when it walks up the perpendicular wall, or even along the ceiling. The fineness of the points,

in which they terminate, renders it practicable for the fly, to fasten itself even to the glass of the window, which is perpendicular, or the looking-glass hanging against the wall; for though their surface appears to us perfectly smooth, it affords hold for these slender hooks."

Little bits of Caroline's fine flaxen hair appeared under the microscope as big as the barrels of large quills, fig. 17, and hollow within. Seen by means of the solar microscope they were like large poles, and their tubular structure was more conspicuous.

Caroline thought of looking at her needle through the microscope. She wondered how fine the point must be, with which she could sew so quickly and so neatly: and was not a little surprised, to see how huge it appeared in comparison with the claws and bristles of the fly's foot. It looked like a thick iron bolt, rough from the smith's hand (fig. 18); and the point was blunt and rounded, so that it seemed impossible for it to pierce the skin.

But the most beautiful of all was a little bit of one of the wingcases of a cock-chaffer. Looking at it first with the naked eye, we saw nothing but a bit of a thin light-brown

substance, in which we could not suppose there was any thing singular. But we were agreeably deceived, when we looked into the microscope. The piece then, as much of it as we could see, was of a golden colour, spotted like the skin of a leopard, with a brown and yellow border, as at fig. 19. Brown, annular spots were scattered over the yellow surface; and on the edge, that was not torn, were three brown stripes. When the light of the Sun was suffered to fall upon it through the glass, the brilliancy was beyond description fine, but so dazzling, that, to see it clearly, it was necessary to moderate the light. The solar microscope exhibited it in a very splendid manner, and from that my drawing was made, which, however, is far short of the beauty of the original.

Your affectionate brother,

WILLIAM GOODWIN.

CHAP. XXXII.

THE FIRE OF BAKU.

THE city of Baku, or Badku, on the borders of the Caspian sea, and about three miles from the southern arm of the Caucasian mountains, is seated in a delightful country, part of which has ever been distinguished by the name of the Paradise of Roses. It has long been famous for its springs of *naphtha*, a species of bitumen, or fossil oil, which, when pure, is white, very light, very fluid, and highly inflammable.

About two miles east from one of the purest naphtha springs is a very singular spot, called *Atoshyah*, or the *Place of Fire*. On approaching this place a strong smell of sulphur is perceived. The place itself is near three quarters of a mile over; and in the middle of it, when the weather is dry, may be perceived a strong bluish yellow flame, which appears larger by night than by day. At a little distance from this flame, the *guebres*, or *gebers*, an asiatic people, who worship fire,

and other poor persons, have built little stone habitations. The ground within the single room, which these huts contain, is covered with a floor of clay a foot thick, rammed down hard, that the flame may not burst through. In one place, however, a hole is left in the clay floor, to furnish fire when necessary; and when the host has occasion to boil his coffee, or dress his food, he holds a lighted candle, or a bit of burning paper over the hole, and a flame is immediately produced, which he knows how to employ for his purpose better than he would a fire made with coals or wood. The smaller the opening is, with the more force rises the flame. From an opening of two inches diameter it reached at first a height of three feet ten inches, but afterward fell to two feet five. When the fire is no longer wanted, the host blows it out with a fan, or the flap of his garment, and then covers the hole.

These people procure light in the same manner. Into a slender hole made through the clay floor they stick a reed, of such height as they think proper, previously coated both on the inside and outside with clay, and kindle the vapour as it issues out at the top.

The weavers have several such round their looms, which afford them an ample supply of light, without requiring to be trimmed or renewed.

This fire is not wanted to yield warmth in winter, for in that climate it is sufficiently hot for the people to leave their doors open all the year round.

Beside this consuming fire, there is another kind at Baku, which does not burn. When, after a warm autumnal rain, the evening air is warm likewise, the fields round Baku appear in flames. It frequently seems as if huge volumes of fire rolled down the mountains with incredible velocity. In October and November, on clear moonlight nights, all the mountains west of Baku often appear enveloped in a blue flame. In warm and dark nights, innumerable flames, sometimes separate, sometimes united together, cover the plains; and then the mountains are free from them. These frequently fill the space where a caravan has encamped, to the great terror of the horses and mules.

This fire burns nothing. The dry grass and reeds remain unfinged, though the whole country appears in flames. It does not even

yield the least heat. This fire, as it is called, must be merely a luminous appearance therefore, and totally distinct from the former.

It is to be observed, that light and heat, though they are so commonly found together, and appear on different occasions capable of mutually producing each other, so that the ideas of both become almost inseparably associated in our minds with that of fire, are probably to be considered as perfectly distinct from each other; and we are told, that the celebrated Dr. Herschel has lately discovered a method of separating them.

A remarkable circumstance, respecting the fire, or more properly the light, of which we have been speaking, is, that it will remain for some minutes attached to the outside of a glass exhausted of air, like a phosphorescent appearance. Exhausted glass tubes appear strongly luminous, and as if filled with fire, for some minutes after the flame in the open air is extinguished: whence we may infer, that electricity has a share in this singular phenomenon.

CHAP. XXXIII.

AN EXTRAORDINARY EATER.

MANY of our readers, no doubt, have heard of a stone-eater, as he was called; a man who gained a livelihood by going about as a show, swallowing pebbles, and champing to pieces and swallowing bits of stone. We do not know the fate of this man; though it does not appear, that he lived long under this practice. The human stomach can accommodate itself occasionally to improper substances in a wonderful manner, so that every accidental swallowing of an indigestible substance is not necessarily fatal: but this can never be practised long with impunity; and instances of such violent suffering from a single imprudence of the kind have been known, that we cannot be too cautious, in never allowing ourselves even to hold in the mouth a pin, a pebble, or even a plum-stone, much less to swallow them. A still more extraordinary instance than that of the stone-eater, however, is the following; the subject of

which suffered much from his imprudence, and at length fell a victim to it.

Andrew Basile, a galley-slave at Brest, came into the naval hospital on the 5th of September, 1774. He complained of a cough, oppression at the stomach, and pains in the bowels, for which Dr. de Courcelles, the hospital physician, prescribed some medicines, that seemed to mitigate his complaints. He was still in the hospital in the beginning of October, when he fell under the care of another physician, Dr. Fournier. He was then tormented with pains in his stomach, and frequent vomiting, which rendered him very low: but the physician obtained no information from him, that could lead to a knowledge of the cause of his disorder; and accordingly prescribed such medicines, as he judged to be most suitable to his complaints. On the 10th of October he died.

Dr. Fournier conjectured, that he must have had some peculiar affection of the internal parts, and the next day opened the body. The stomach appeared to be thrust out of it's usual situation, and various hard substances were felt in it, though what they were could not be ascertained by the feel.

Through an accidental opening made in it, however, Dr. Fournier saw a piece of wood, of a black colour, protrude; and in consequence he deferred any farther examination of this singular case, till the arrival of a company of physicians, surgeons, pupils, and officers, whom he invited to be present. At three o'clock they were all assembled, to the number of fifty, and in the presence of these eyewitnesses, an account of the whole was drawn up. The stomach, as well as the œsophagus and bowels, was internally of a blackish colour, and the following is an inventory of the articles it contained.

1. A piece of an iron hoop, nineteen inches long, and an inch broad.
2. A piece of broom, six inches long, and half an inch thick.
3. Another piece, of the same thickness, eight inches long.
4. Another such piece, six inches long.
5. Another, four inches long.
6. Another piece, four inches long, split nearly in the middle.
7. A piece of oak, four inches and half long, an inch and half broad, and half an inch thick.

8. Another piece, four inches long, an inch broad, and two thirds of an inch thick.

9. Another piece, four inches long, half an inch wide, and a third of an inch thick.

10. Another piece of the same dimensions.

11. Another piece, two inches long, an inch broad, and half an inch thick.

12. Another piece, four inches and half long, a third of an inch broad, and a third of an inch thick.

13. Another piece, four inches long, and of a triangular figure.

14. Another piece, four inches long, and a third of an inch in diameter.

15. Another piece, five inches long, half an inch broad, and two lines thick, split lengthwise.

16. Another piece, five inches long, a third of an inch broad, and two lines thick.

17. Another piece, of an irregular figure, three inches long, and a quarter of an inch thick.

18. Another piece, three inches long, half an inch broad, and a quarter of an inch thick.

19. A piece of a hoop, five inches long, an inch broad, and two lines thick.

20. A piece of fir, four inches long, an inch broad, and near half an inch thick.

21. Another piece, four inches long, and a third of an inch in diameter.

22. Another piece, in the shape of a wedge, two inches and half long, one inch broad, and a third of an inch thick at the base.

23. Another piece, of an irregular figure, three inches long, and half an inch thick.

24. Another piece, two inches and half long, and a third of an inch thick.

25. A piece of bark from a hoop, three inches and half long, and an inch broad, belonging to a larger piece, which still stuck in the œsophagus, and from which this had been broken off, and fallen into the stomach.

26. A wooden bung, an inch long, and the same in diameter.

27. A wooden spoon, gnawed at the lower end, five inches long, and an inch and half broad.

28. The nosle of a tin funnel, three inches and half long, an inch in diameter at the larger end, and half an inch at the smaller.

29. Another piece of a tin funnel, two inches and half long, and half an inch thick.

30. The handle of a pewter spoon, four inches and half long.

31. A pewter spoon entire, seven inches long, the bowl bent round.

32. A smaller spoon of the same metal, three inches long.

33. Another, two inches and half long.

34. A piece of iron, two inches and half long, half an inch broad, and a third of an inch thick.

35. A pipe-case, with the edges blunted, and a piece of the stem, all together three inches long.

36. A nail, the point broken off, two inches long, including the head.

37. Another nail, very sharp, an inch and half long.

38. A piece of a pewter spoon, squeezed flat, an inch long, and half an inch broad.

39. Two pieces of a pewter buckle, of irregular figures, each about half an inch long.

40. Five plumb-stones.

41. A little piece of horn.

42. Two pieces of flint glass, the largest an inch and one third long, half an inch broad, and of an irregular shape.

43. Two pieces of leather, the largest three inches long, an inch broad, and of an irregular figure; the other an inch and a third long, and half an inch broad.

44. A knife, with it's blade bent, the haft of wood, three inches and half long, and an inch broad in the widest part.

Thus the whole of this singular store consisted of fifty two articles, weighing above two pounds.

One of his countrymen, who had been sent to the galleys with him, said, that he had often seen him scratch down mortar and plaster from the wall, and throw it into his soup, saying, that it was a cordial to him, and comforted his heart. Sometimes he had a raging appetite, which announced itself by an abundant flow of spittle, and could then eat as much as four people. When this was the case, and he could not satisfy his hunger, because he had spent his money in tobacco, of which he was very fond, he used to swallow little stones, buttons, pieces of leather, and other such things. His comrades at the oar had seen him swallow two pieces of wood, four or five inches long, two days before he went to the hospital: but it was not known

when he had swallowed the great piece of an iron hoop nineteen inches in length. He long complained of pains in his inside; but had never mentioned any thing relative to his singular diet, except once saying, that he had a thousand devilish things within him, which would be his death. At times, however, he appeared to be disordered in his mind.

CHAP. XXXIV.

SPONTANEOUS COMBUSTIONS.

It has long been known to chymists, that there are substances, which, though perfectly cold, when mixed produced heat, and even actual fire. Thus in the curious experiment called Lemery's volcano, a large quantity of iron-filings and flowers of sulphur, being mixed with so much water as will make it into a paste, and then buried in a hole in the ground, will grow hot, and after a time cause the earth over it to swell up, till at last it cracks, and flames issue out.

Of late years, however, some serious accidents have called the attention of men of science to the subject, and it has been found, that many other substances, when mixed together, or packed up close, or exposed to a certain degree of warmth, grow very hot. Ricks of green hay, and dunghills, sometimes grow so hot, as to take fire spontaneously; and greasy cloth laid in heaps together, various articles that have been roasted, and other things, are liable to the same danger. Many fires may have been occasioned in this way, that were afterward attributed to malicious design, because the manner in which they were produced could not be discovered. It is not sufficient, to take care of fire and candle, though this is highly necessary; for there are many other things, of which we ought to be as careful, though neither fire nor light is apparent in them. The following are examples.

At a sail-cloth manufactory several pieces of coarse hempen canvas, painted on one side with brown paint mixed with oil, were laid in the sun to dry. It was a very hot day in July, so that it dried very quickly, and was considerably heated; when, in the afternoon,

there being an appearance of a heavy storm, it was hastily taken in, the painted sides being laid one upon the other, and the whole being folded up in bales, and tied tightly together, to remove it more conveniently. These bales were placed in the workshop, which was shut up at night.

Two days after, one of the workmen sat down upon these bales, and found them hot. He thrust his hand in between the folds, but the heat soon made him draw it out again. The bales were taken into the open air, and as soon as the men began to unpack them, a thick smoke issued out. It was at first supposed, that they had been purposely set on fire: but no trace of such a thing could be found, and, as soon as they were completely unfolded, all suspicion vanished; for it was clearly seen, that the fire began in the centre of the bales, the outside remaining untouched, while the inner folds, particularly where pressed together tightly by the cords, were burned to ashes.

Some of the workmen then confessed, that a similar accident had happened a few years before, which they had concealed, for fear it

would be ascribed to their negligence, and they be punished.

Similar instances have occurred more than once with woollen cloth, the wool for which is well oiled before it is carded and spun. Various pieces of serge, being laid upon one another, without being cleansed from the oil, heated to such a degree, that the undermost, without emitting either flame or smoke, were converted into a black, shining, brittle substance, which smelled like burnt horn, melted over the fire, and burned with a flame like resin.

A mixture of linseed oil and lampblack is a very dangerous combustible.

In August 1780 a fire broke out in a warehouse at Petersburg, by which a great quantity of hemp was consumed. On inquiry there appeared reason to suppose, that it was occasioned by a mixture of this kind. To obtain strong assurance of the fact, five and thirty pounds of hemp-seed oil varnish were poured upon forty pounds of lampblack in a tub, under the inspection of the imperial academy. After standing an hour, the superfluous oil was poured off. The residuum was left in the tub four hours, then rolled up

in a hammock, and laid in a ship's cabin, where a suspicious fire had broken out, which was said to have been produced by such materials. The door was sealed up, a guard set over it, and four naval officers were directed to watch the appearances attentively all night. The experiment was begun on the 26th of April, 1781, at eleven o'clock in the forenoon. The next morning at six smoke appeared issuing out of the hammock, and, as soon as the door was opened, it burst into flames.

The admiralty directed another experiment to be tried. Three pounds of lampblack were slowly mixed with five pounds of hemp-seed oil varnish; and after the mixture had stood five hours in an open vessel, it was tied up in linen, and placed in a box. Sixteen hours after an offensive, stinking smell was perceived, but not like that of boiling oil. Some parts had grown hot before this. The vapour, that arose, was not inflammable, but watery. Eighteen hours after the mixture had been packed up, more places grew hot, began to smoke, and soon after appeared glowing with fire. Other places still were scarcely warm. The fire spread in the mix-

ture but slowly, and emitted a thick, dark, stinking, footy vapour. When the bundle was taken out of the box, and laid on the stone floor, so that the air had free access to it, flames burst out, with thick smoke. Soon after clefts appeared here and there, from which issued vapours, that soon rose into flame. On breaking the lumps a little, they burst into a violent flame, near a yard high, but it soon diminished, and went out. The smoking, glowing, and flaming fire, however, continued for six hours; and the mass remained redhot for two hours after this. The gray, earthy ashes, that were left, weighed, when cold, three ounces and half.

A perfectly similar mixture being made, the fire did not take place till one and forty hours after.

A pack of hemp weighing thirty pounds was greased with a mixture of six pounds of hemp-seed oil and a pound of tallow, placed in an oven for an hour, rolled up in a mat previously warmed, and laid on some faggots. In an hour's time the pack began to heat; in three hours it emitted smoke. Being opened, it appeared on fire in two places; burned four hours with flame; and then continued glow-

ing, till in thirty two hours it was reduced to ashes.

Twenty pounds of wool were greased with a mixture of two pounds of hemp-seed oil, and one pound of tallow. The wool was placed in an oven for an hour, and then tied up in a warm mat. The bundle remained cold three days, the wool having absorbed all the grease. Another pound of hemp-seed oil, therefore, was poured on it; it was put into the oven again for an hour; and, being tied up in a coarse cloth, was laid on some faggots. It now began to smoke, and in four hours time was on fire. The fire burned without flame, as long as the pack remained tied up; but as soon as it was opened, a low flame issued from it. After it had continued burning forty hours, the fire went out.

Old cloth garments drenched with hemp-seed oil, dried in an oven, and rolled up together, remained without heating. But when, in addition to this, they were greased with tallow, put into the oven afresh, and again rolled up, they grew hot, in three hours time smoked, and in four and twenty hours the bundle was found charred and smouldering.

At length it took fire, and was four days before it had burned out.

Cow's hair, besmeared with tallow, warmed in the oven, and put into a bag of matting, grew hot in an hour and a quarter. It began to stink, to smoke, and in an hour after burst into flames.

A quantity of rye bran, weighing two pounds, was roasted in an old copper pot, on a coal fire, stirring it constantly, till it was as brown as pale coffee; when it was poured out hot into a piece of linen, and tied up in it. In three hours heat and smoke were perceived, some spots burned black appeared, then glowing fire, and this continued six hours. On repeated trials, the browner the bran was roasted, the sooner it caught fire.

Rye flower, and wheaten flower, roasted like coffee, and tied up in linen, took fire in seven minutes after they were packed up: pearl barley, in half an hour: and barley-meal, in fourteen hours.

Rice, roasted very brown, and packed up, was merely charred, and the outside scaled off.

Pease, roasted, pounded, and packed up, burned fiercely in half an hour.

Coffee berries, roasted, and packed up, did not take fire. But when they were first roasted, then ground, afterward roasted again, and packed up hot in a linen cloth, the coffee took fire in three quarters of an hour.

Beans, roasted, and packed up, did not take fire : but bean-meal, treated in the same manner, did.

Various kinds of herbs, dried, powdered, roasted brown, and packed up, took fire in a longer or shorter time.

Coarse sawduft, roasted and packed up, took fire in an hour.

Hence it appears, how dangerous many things of this kind may prove ; and how much precaution is necessary on many occasions, where commonly nothing is apprehended.

CHAP. XXXV.

SPONTANEOUS COMBUSTIONS OF THE
HUMAN BODY.

It has been seen in the preceding chapter, that various substances, or combinations of substances, under certain circumstances, are disposed to generate heat, even to such a degree as to consume themselves. But, what is more surprising, and would indeed be incredible, were it not confirmed in more instances than one by testimonies of such authenticity, that we cannot refuse our belief, our own bodies, while living, may become so combustible, as to burn away without the aid of extraneous fuel; nay, it should seem, they may even be consumed by fire, spontaneously generated within them.

In the Transactions of the Royal Society of Copenhagen we read, that, in 1692, a woman of the lower class, who for three years had used spirituous liquors to such excess, that she took scarcely any other nourishment, having sitten down one evening in a straw-

chair to sleep, was consumed in the night-time, so that next morning no part of her was found but the scull, and the extreme joints of the fingers, all the rest of her body being reduced to ashes.

Bianchini, a celebrated physician of Verona, relates the following case very circumstantially. It is attested also by the marquis Scipio Maffei, a learned contemporary of Bianchini, who was far from being credulous; and was confirmed to the Royal Society of London by Paul Rolli.

The countess Cornelia Bandi, of Cesena, aged 62, enjoyed a good state of health. One evening, having experienced a sort of drowsiness, she retired to bed, and her maid remained with her, till she fell asleep. Next morning, when the girl entered her mistress's chamber to awaken her, she found nothing but the remains of her body in a horrid condition. At the distance of four feet from the bed lay a heap of ashes, amid which were the arms, and the legs with the stockings on them. Between the legs lay the head; but the brain, half the hinder part of the scull, and the whole of the chin, were consumed. Three fingers were found burned to a coal:

the rest of the body was reduced to ashes, which, when touched, left on the fingers a greasy, fetid moisture. A small lamp, which stood on the floor, was covered with ashes, and contained no oil; the tallow of two candles was melted on a table, but the wicks still remained. The bed was not damaged; and the bedclothes had been lifted up, and thrown on one side, as when a person gets out of bed. The floor was covered with a thick, slippery moisture, which adhered to it very tenaciously. The furniture and tapestry were covered with a moist kind of soot of the colour of ashes, which had penetrated into the drawers, and soiled the linen. This soot had diffused itself into a kitchen adjoining, adhered to the walls and utensils, and covered a piece of bread in the cupboard, which no dog would touch. In the chamber over the apartment of the countess, a yellowish, greasy, offensive fluid trickled down from the windows. The air in it likewise was loaded with that fine soot, and an unusual offensive smell: and this noisome odour gradually spread into the adjacent apartments.

We do not know how far the countess had been addicted to the internal use of spirituous

liquors, but she had been accustomed to have her body bathed all over with camphorated spirit of wine.

A third example, we shall mention, occurred in France; and the following is the report of it, drawn up by Mr. Merille, a surgeon of Caen, at the request of the officers appointed to examine into the fact.

“ The body of Mrs. Thuars lay with the crown of the head resting against one of the andirons, at the distance of eighteen inches from the fire : the remainder of the body was in an oblique position before the fireplace, the whole being a heap of ashes. Even the most solid bones had lost their firm consistence; so that none were distinguishable, except the coronal, the two parietal bones, two of the lumbar vertebræ, part of the tibia, or large bone of the leg, and a part of the scapula or bladebone; and these were so calcined, that they crumbled to dust on the least pressure. The feet, however, remained; but the right was scorched at the upper joint, and the left was more burnt. The day had been cold, but there was nothing in the grate, except two or three bits of wood, about an inch in diameter, burnt in the middle. None

of the furniture in the apartment was damaged. The chair, on which Mrs. Thuars had been sitting, was found at the distance of a foot from her, and absolutely untouched. I must here observe, that this lady was exceedingly corpulent, above sixty years of age, and much addicted to spirituous liquors; that on the day of her death she had drunk three bottles of wine, and about a bottle of brandy; and that the consumption of the body had taken place in less than seven hours, though, according to appearance, nothing around the body was burnt but the clothes."

Many other cases are on record, more or less circumstantially related, and more or less credibly authenticated, but we shall conclude with two, that happened in this country, and appear to be sufficiently confirmed.

Grace Pitt, the wife of a fishmonger of Ipswich, about sixty years of age, had contracted a habit, which she continued for several years, of coming down every night from her bed-room, half dressed, to smoke a pipe. On the night of the 9th of April, 1744, she got up from bed as usual. Her daughter, who slept with her, did not perceive she was absent, till next morning, when she awoke;

soon after which she put on her clothes, and went down to the kitchen, where she found her mother, stretched out on her right side, with her head near the grate, the body, having the appearance of a log of wood, consumed by a fire without apparent flame, extended on the hearth, and her legs on the floor, which was of deal. On beholding this spectacle, the girl ran in great haste, and poured over her mother's body some water, contained in two large vessels, in order to extinguish the fire; while the fetid odour and smoke, which exhaled from the body, almost suffocated some of the neighbours, who had hastened to the girl's assistance. The trunk was in some measure incinerated, and resembled a heap of coal, covered with white ashes. The head, the arms, the thighs, and the legs, had also participated in the burning. This woman, it is said, had drunk a large quantity of spirituous liquors, in consequence of being overjoyed, to hear that one of her daughters had returned from Gibraltar. There was no fire in the grate, and the candle had burned entirely out in the socket of the candlestick, which was close to her. Besides, there were found near the consumed body the clothes of a child,

and a paper screen, which had sustained no injury by the fire. The dress of this woman consisted of a cotton gown.

Mary Clues, fifty years of age, was much addicted to intoxication. Her propensity to this vice had increased after the death of her husband, which happened a year and half before. For about a year, scarcely a day had passed, in the course of which she did not drink at least half a pint of rum, or aniseed water. Her health gradually declined; and about the beginning of February she was attacked by the jaundice, and confined to her bed. Though she was incapable of much action, and not in a condition to work, she still continued her old habit of drinking every day, and smoking a pipe of tobacco. The bed, in which she lay, stood parallel to the chimney of the apartment, and about three feet distant from it. On Saturday morning, the 1st of March, she fell on the floor; and her extreme weakness preventing her from getting up, she remained in that state, till some person entered, and put her into bed. The following night she wished to be left alone. A woman quitted her at half after eleven, shut the door, and locked

it, according to custom. She had put on the fire two large pieces of coal; and placed a light in a candlestick on a chair at the head of her bed. At half after five in the morning a smoke was seen issuing through the window, and the door being speedily broken open, some flames, which were in the room, were soon extinguished. Between the bed and the fireplace were found the remains of the unfortunate woman. One leg and a thigh were still entire; but nothing was left of the skin, the muscles, and the intestines. The bones of the scull, body, and arms, were wholly calcined, and covered with whitish ashes. The people were much surprised, that the furniture had sustained so little injury. The side of the bedstead next to the chimney had suffered most, the wood being slightly burnt: but the featherbed and clothes were safe. Mr. Wilmer, a Surgeon of Coventry, from whom the above account is taken, says, that he entered the apartment about two hours after it had been opened, and observed, that the walls and every thing in it were blackened, and that it was filled with a very disagreeable vapour, though nothing except the body exhibited any strong traces of fire.

In each of these cases, and all the others recorded, the persons, to whom these distressing accidents happened, had been notoriously addicted to the drinking of strong liquors; one excepted, the countess Bianchini; and she, of whom nothing of this kind is said, was accustomed to bathe the body all over with camphorated spirit of wine. The inflammable matter, therefore, furnished by these liquors, appears to have been the chief cause of the extraordinary combustibility of these unhappy persons, whose fate may serve as an additional warning against the use of intoxicating liquors, which have occasioned more bodily disease, and mental infirmity, than any thing else produced by nature, or invented by man.

CHAP. XXXVI.

DOES MAN SWIM BY NATURE?

THIS question, put in this general manner, does not well admit of a direct answer: we will enter into the subject, therefore, a little more particularly.

Is a man specifically lighter than water?

To solve this question, it is requisite, to make a number of experiments with persons of different ages, and different make. Experiments of this kind are attended with difficulty, and we have too few of them. The following of Mr. Robertson are the best.

He took a water-cask, six feet and half high, and two feet and half in diameter at each end. Ten persons, different in height and bigness, submitted to the experiment. He would willingly have had them so, that there should have been a fat man and a lean man of each different height; but he could not get them exactly as he wished. A proper quantity of water being put into the cask, which stood upright on one end, each of the persons was immersed in it, and the height, to which the water rose, was measured. The height of the water before the person's immersion being deducted from this, the remainder gave the cubical contents of the body immersed; from which, and the absolute weight of the body, the specific gravity was easy to be found.

The following table exhibits the results of these experiments.

Men. Their absolute weight. Weight of the water displaced by them.

1	161 lbs.	160.8 lbs.
2	147	161.6
3	156	156.6
4	140	172.6
5	158	183.7
6	158	176
7	140	170.1
8	132	156.6
9	121	151.5
10	146	146.9

Thus, of these ten men, one only appeared to be a little heavier than water; all the rest were lighter, and some indeed much lighter. We cannot rely implicitly on these experiments, however; for Mr. Robertson confesses, that they were not so perfect, as might have been wished. The persons were impatient to get out; would not remain long enough with the head under water; and rose up quickly, so that the surface of the water was not suffered to come to a perfect level. In consequence, the height of the water was not measured with sufficient accuracy.

From these experiments, however, it sufficiently appears, that the human body in

general is at least as light, if not lighter, than water. A thin, rawboned person may perhaps be a little heavier than water, than fresh water at least: while those who are fat, and whose bones are slender, will probably be found much lighter. If a person bathing let himself sink in the water, where it is not too shallow, and remain motionless, he will find himself carried along by the stream, without sinking to the bottom. In such experiments some difference is made by inspiring or expiring before stopping the breath; for when the lungs are full of air they occupy more room by some inches, and thus diminish the specific gravity of the body.

But the question, whether man swim naturally, does not turn on his specific gravity alone. Man cannot live without breathing. If, therefore, he be not heavy enough, to sink to the bottom, when wholly or nearly immersed in water, this is not sufficient. The head must be so far out of water, that he can breathe through the nose at least, if not through the mouth, or he will be suffocated. Most people will find the exertion of some power necessary to effect this; and must therefore move their limbs in such a

manner, that the resistance of the water to their effort shall impel the body upward again when sinking. If the hands and feet be moved in a perpendicular direction, this will effectually keep the head above water, but it will not produce any change of place. For this purpose it is necessary, that the hands, or feet, or both, be moved in an oblique direction, which will impel the body forward, at the same time that it raises it in the water.

A man may swim either in a perpendicular position, or in a position nearly horizontal. In the latter case he may swim either on his back or on his belly.—Swimming in a perpendicular position has the advantage of being a posture, to which man is accustomed, and in which he may move his limbs nearly as in walking: hydrostatically considered, however, it has the disadvantage of requiring the whole head to be kept above water, which is not necessary in swimming on the back; and the swimmer cannot employ his exertions with so good effect to propel himself forward, as in the inclined position, while at the same time his progress is retarded by the resistance of the

water to a greater surface. The art of keeping the body perpendicular, by moving the feet alone directly upward and downward, the hands remaining at rest, is called treading water.

Swimming on the belly is perhaps the most laborious mode, because the body is in an unusual posture, and the limbs are employed in a manner, to which they have not been accustomed. It is the best, however, for advancing forward, because the efforts of both hands and arms are employed to most advantage, and the resistance of the water is but small. The nearer the body is to a horizontal position, the less this resistance, and the greater the propelling power. In this mode, however, it is equally necessary, to keep the head above water.

Swimming on the back is the easiest mode of all, because in this position the greater part of the head may be under water, for, if the nose and mouth be above the surface, it is sufficient. Hence, as very little of the body is to be kept above water, little effort is required for this. In this position the feet can act very efficaciously, but the hands have little power, to propel the body forward.

As it is not our business here, however, to teach the art of swimming, but to explain it's physical principles, we must refer for farther instructions to Bernardi's Treatise on Swimming*, Salzmann's Gymnastics for Youth†, and the Encyclopedia of Bodily Exercises§.

CHAP. XXXVII.

ARTIFICIAL HELPS FOR SWIMMING.

SWIMMING is such an agreeable exercise, that many, who have not sufficient skill, to keep themselves properly above water, would gladly participate in the healthful amusement it affords. It is laborious, likewise, to those,

* This is a german book; but there is an english translation of a little treatise on the art by Thevenot, which is a useful tract.

† A translation of this work has been published by J. Johnson, St. Paul's Churchyard.

§ This is a german work, in 3 large vols. 8vo, by the author of the Pleasing Preceptor.

to whom considerable practice has not rendered easy the movements it requires. Some, too, have been afraid, to rely entirely on their own powers, lest the cramp, or any other accident, should suddenly deprive them of the capacity of exerting them: Hence long ago men began to turn their minds to artificial helps, capable of sustaining them in the water without any action of their own, so that they should have no occasion for exerting any power, except to impel themselves forward, and might rest whenever they pleased.

These helps may be divided into two classes: such as swim, and help to support the body, by their little specific gravity; and such as produce the same effect by their form.

To the first class belong cork, light wood, reeds, and the like, placed under or about the breast. Of these, cork is particularly serviceable, from it's little specific gravity, as it has not one fourth of the weight of water. A well dried piece of cork, indeed, will not sink above a sixth or eighth part of it's bulk in water: but when it is used for swimming, the body it supports will press it down, and

the water will insinuate itself into the large interstices, expel the air, which rendered it so light in appearance, and reduce it to it's real specific gravity. That this is the fact may be seen by holding a piece of very dry cork under water, when the air, then expelled, will ascend to the surface in bubbles.

The use of cork for the purpose of swimming has long been known. Among the ancients it was considered as an accomplishment, *sine cortice natare*, to swim without corks: on the other hand, not to be able to swim was ranked with not having learned to read. *Nec literas nec natare scire*, was a proverbial expression for a man completely ignorant: the man, who could neither read nor swim, it was supposed, could know nothing.

Cork is not only light, but very conveniently applicable to the purpose, as it is easily cut into any shape, and is neither hard nor unpliant. It may be used in various ways. Whole pieces may be taken, and made into a sort of cuirass: or it may be cut into slips, and these stitched between two pieces of linen, cotton, or flannel, so as to make a waistcoat. These are the best modes of

using it; but the most common is, to take a few pieces of cork, string them on a cord, and confine them by tying a knot at each end. The swimmer lays his breast on the middle of this cord, in such a manner, that the corks, equally divided, lie just behind the armpits. A broad belt, however, is better for this purpose than a cord, as it will be less uneasy to the swimmer: but, whichever of these is used, there should be another cord or belt fastened to the middle of it, forming a loop to go round the neck, that the corks may not slide down under the belly, which would imminently endanger the swimmer's life.

How much cork is necessary, to enable a man to swim?

This of course must depend on the specific gravity of the person, and his absolute weight; from which, if they be known, and the specific gravity of cork, an answer to the question may easily be found. That my young readers may know how to answer similar questions themselves on occasion, I will state a case for their instruction.

Suppose the person, when immersed in water up to the neck, occupies the space of

two cubic feet : he will then lose as much of his own weight as equals the weight of two cubic feet of water, or 123 pounds. Allow his absolute weight to be 135 pounds; and the specific gravity of cork to be one fourth of that of water. The weight of the cork required we will represent by x . The young reader must not be staggered at the algebraic mode of notation by letters and signs; for, instead of rendering things difficult and mysterious, it makes them easy and evident, as soon as their *signification* is understood.

Now the x lbs. of cork, when wholly immersed, will displace $4x$ lbs. of water; and the weight of the person and the cork, $135 + x$, must equal that of the water displaced by both, $123 + 4x$, in order that the person may swim as required. Hence we have the following equation.

$$123 + 4x = 135 + x.$$

Consequently $123 + 3x = 135$.

Therefore $3x = 135 - 123 = 12$.

Whence we find $x = 4$.

Four pounds of cork, therefore, will keep such a person from sinking, so that he will remain with his head completely above water.

The second class of artificial helps for swimming are such as support the body by their figure, that is, by being hollow, so as to include air within them.

Of these the principal are bladders. These are so far convenient, that a pair may be carried with ease in the pocket, while not inflated; and when the person arrives at the water's side, he may soon blow them up, and put them on. They are used in the same manner as corks; the caution given above respecting which is equally necessary with them: but, like the rest of this class, they are not so secure as cork, for a hole accidentally made in one of them, or the slipping of the string, may deprive the swimmer of their assistance unawares. Indeed a person, who cannot swim tolerably well, should on no account venture out of his depth with bladders. A learner, who finds it difficult to acquire the art of swimming, either from weakness or awkwardness, may find them of service, to support him in the water, till he is enabled by practice, to move his legs and arms with more effect and less fatigue: but this he may do equally well without going out of his depth, and then, if the bladders

be properly secured from slipping down below the breast, he will be safe from danger.

Inflated skins were used for swimming in ancient times. Livy speaks of this, by the by, as a common practice among the Spaniards in those days. Kepler's swimming girdle is made of leather, hollow, and inflated.

The aquatic shield proposed by Wagenfeil is equally insecure, and more incommodious, as it consists of a hollow box of wood fastened round the body.

Cork, indeed, is the best and most secure of all artificial helps, though not so convenient for carriage as bladders.

For those, who can swim by the exertion of their own powers, all these helps are unnecessary; unless in sea voyages, when it would be prudent, perhaps, for every one, to provide himself with a cork waistcoat, that he might incur less danger in case of shipwreck.

On this occasion we must not omit the simple contrivance of the Chinese; which consists of four pieces of thick bamboo, about two feet long each, tied together at a little distance from the ends, so as to form a square opening in the middle, through which the

head and arms are thrust. These are then secured from slipping down, and will support a person in the water effectually.

CHAP. XXXVIII.

OF THE DIVING-BELL.

As we sometimes find it necessary, to support ourselves on the surface of the water, there are other occasions, on which it would be convenient for us, to stay some time beneath. But a man cannot remain under water, without being suffocated, longer than he can dispense with taking breath. By practice from an early age, a person may acquire a capacity of remaining under water for a few minutes, without injury : and it is well, to acquire this capacity, as it may be useful on many occasions.

But as this capacity in general can be acquired only to little extent, it is much more convenient for a man, to descend into the water surrounded by air, so that he may

continue there to breathe as usual. Hence long ago attempts have been made, to contrive means of descending under water, without danger of being drowned, and even of doing many things in that situation. The possibility of such a proceeding may be seen by an experiment easy to be made, which probably first led to the invention, in modern times so celebrated, under the name of the *diving-bell*.

Take a short bit of wax taper, stick it on a piece of cork, light it, and set it on the surface of a bucket of water. Invert a drinking glass, place it over the taper, and depress the glass, till the water covers it. You will see, that the water rises a very little way in the glass, but the upper part of the glass will remain full of air, in which the taper, floating on the surface of the glass, will continue to burn, till the air is rendered incapable of feeding the flame.

What the drinking glass is in this experiment in little, the diving-bell is on a larger scale. This machine has been brought to a considerable degree of perfection in modern days, though the invention itself appears to be of considerable antiquity. Even Aristotle

mentions, that divers made use of a caldron, to enable them to remain longer under water. This, however, is not perhaps to be considered as an account of what might properly be called a diving-bell. The translators of the greek original, indeed, have added, that the divers inverted the caldron over their heads, and thus descended into the water. But Aristotle himself does not expressly say this; his words seem rather to imply, that such caldrons, full of air, were sent down to the divers, when they had been some time under water, that they might take breath in them, and so recruit themselves, to remain under water afresh.

In the time of Charles the fifth, something more precise on the subject occurs. Taisnier, who was governor to the pages of that emperor, saw an experiment at Toledo, in 1538, which two greeks performed in the presence of that emperor, and which he describes in the following manner.

“ If the ignorant vulgar were told, that a person could descend amid the waves of the Rhine to the bottom of the river, without wetting his clothes, or any part of his body; nay that he could bring up fire burn-

ing through the water; they would laugh at the narrator, and declare it to be impossible. Yet this I myself saw, in the year 1538, in the spanish city of Toledo; where the experiment was made in the presence of the emperor Charles the fifth, and near ten thousand spectators, by two greeks. These men took a large caldron, inverted it, and suspended it by a rope. In the cavity of it they fixed cross pieces of wood, to support themselves and the fire. Round the rim of the caldron they fastened pieces of lead, which were equally distributed, so that the caldron hung evenly balanced, with the brim in a horizontal position. This was done, that one part might not touch the water sooner, or with more force than another; otherwise it might easily have happened, that the water would overpower the air included in the caldron, and resolve it into a fluid.*

* It appears, that the writer of this account had very erroneous ideas on this subject. The fact is, if one side of the vessel were heavier than the other, the brim would touch the water obliquely, and so include less air, because the air would have a free passage out, till the higher part of the brim was immersed. Besides, the vessel not being exactly balanced, the upward pressure of the air, in descending, would be stronger.

If, however, the caldron, thus prepared, be let down into the water with sufficient slowness, the air, enclosed in it by means of the water, will make itself room. Accordingly, the men in the machine will remain perfectly dry amid the water, till the included air is weakened by repeated breathing, and converted into a less subtil fluid, being absorbed by the dense moisture of the water.* If, however, the caldron be slowly drawn up against the higher side, than against the lower, which would be more perpendicular; so that it would raise the higher side still more, and thus let more air escape, till the vessel would be completely overturned, and filled with water.

* Here again Mr. Taissier is mistaken. The air is not converted into a denser fluid, but rendered unfit for breathing in a different way. The air of our atmosphere is not a simple substance, but a compound; and it is only one of its constituent parts that is capable of supporting life. Every time we breathe, a certain quantity of air is taken into the lungs. These separate from it that part, which is necessary to life, and expire the rest. Thus by repeated breathing in a given quantity of air, the part necessary to life will be gradually consumed, and the remainder will be totally incapable of supporting life; so that a person will as inevitably die in it, as if he were completely immersed in water alone. It is to be observed, the same part of the air,

again in due time, the men will remain dry, and the fire unquenched."

So far this account, the oldest we have, of the important invention of the diving-bell. But this does not prove, who was the first person, that dived under water in a caldron, or other hollow vessel: though we learn from it, that the contrivance was known in the sixteenth century.

In the following century, we know, a machine on this principle was used, for the purpose of fetching up goods from the bottom of the sea. When the Spanish armada was defeated in 1588, some of the ships, that endeavoured to escape by passing round Scotland, were wrecked on the island of Mull. One of these, according to the report of some of the Spaniards, who were saved, had considerable treasures on board. This ancient story tempted persons, from time to time, to make various endeavours for the recovery of the valuables, that were sunk. In 1665, a person succeeded in bringing up a few guns, which supports life, maintains combustion also; so that fire burning in a given quantity of air reduces it to the same state as breathing in it.

but they did not sufficiently repay the expense of the undertaking.

Some years after an attempt of the like kind was once more brought forward. William Phipps, the son of a blacksmith in America, proposed to go down and unload a valuable spanish ship, which had been lost on the coast of Hispaniola. His scheme appeared so plausible to Charles II, that he furnished Phipps with a vessel, and every thing requisite to the undertaking. Accordingly, in 1683, he set sail; but was unsuccessful, and returned in great distress, though firmly convinced of the practicability of his design. He solicited another ship, therefore, from James II, who had now ascended the throne. Having failed a second time, he sought to carry his enterprise into execution by the assistance of private individuals, and opened a subscription for the purpose. At first he was laughed at; but at length the duke of Albemarle took up the affair, and advanced a considerable sum of money, toward making the necessary preparations for a new voyage. Phipps soon procured the remainder, and sailed in 1687, in a vessel of two hundred tons,

to try his fortune once more. At first all his attempts were in vain: but at length, when his patience was nearly exhausted, he succeeded in bringing up from the depth of six or seven fathoms treasure to the value of three hundred thousand pounds, with which he returned safe to England. Of this he had about twenty thousand pounds for his own share; the duke of Albemarle had ninety thousand; and the rest was divided amongst the other subscribers, in proportion to the sums they had advanced. On his return, some persons would have persuaded the king, to seize the ship and cargo; pretending, that Phipps did not give the king a just account of the business, when he solicited his permission for his voyage. James, however, nobly answered, that he knew Phipps to be an honest man; and that he and his owners should share the whole among them, were it as much again. Not satisfied with this, as a reward for his enterprising spirit, the king conferred upon him the honour of knighthood. Phipps was afterward raised to higher dignities, and died at London in 1693.

On this occasion the duke of Albemarle

solicited from the king the post of governor of Jamaica, to get more out of other ships, that had been wrecked in those parts. But, whether it were, that all the treasure had been gotten out before, or that it had been dispersed by the waves after the ships had gone to pieces, this is certain, that nothing was ever found of sufficient value, to repay the labour of the search.

From the success of these trials, however, others were induced, to make similar attempts in different places, though to little purpose. Of these, that excited most attention, which was made anew near the island of Mull, in 1688, on which occasion the duke of Argyle was the principal person concerned. The divers went down to the depth of sixty feet, remained there an hour at a time, and brought up golden chains, money, and other valuables, but all together to no great amount.

Since this period improvements have been made in the diving-bell, by Dr. Halley, Mr. Triewald, a Swede, and Mr. Spalding, of Edinburgh.

By Dr. Halley's improvement the water was kept entirely out of the bell at any depth, and the air spoiled by respiration

was exchanged for fresh air at pleasure, so that the diver might remain under water as long as he pleased. The following is his own account of the contrivance.

“ The bell I made use of was of wood, containing about sixty cubic feet in it's concavity; and was of the form of a truncate cone, the diameter of which at the top was three feet, at the bottom five. This I coated with lead, so heavy, that it would sink empty; and I distributed the weight so about it's bottom, that it would go down in a perpendicular direction, and no other. In the top I fixed a strong but clear glass, as a window, to let in the light from above; and likewise a cock, to let out the hot air, that had been breathed: and below, about a yard under the bell, I placed a stage, which hung by three ropes, each of which was charged with about one hundred weight, to keep it steady. This machine I suspended from the mast of a ship by a sprit, which was sufficiently secured by stays to the mast-head, and was directed by braces, to carry it overboard clear of the ship's side, and bring it on board again, as occasion required.

“ To supply air to this bell when under

water, I caused a couple of barrels, about 36 gallons each, to be cased with lead, so as to sink empty; each of them having a bung-hole in it's lowest part, to let in the water, as the air in them condensed on their descent; and to let it out again, when they were drawn up full from below. And to a hole, in the uppermost part of these barrels I fixed a leathern trunk, or hose, well liquored with bees-wax and oil, and long enough to fall below the bung-hole, being kept down by a weight appended: so that the air in the upper part of the barrels could not escape, unless the lower ends of these hose were first lifted up.

“ The air-barrels being thus prepared, I fitted them with tackle, proper to make them rise and fall alternately, after the manner of two buckets in a well; which was done with so much ease, that two men, with less than half their strength, could perform all the labour required: and in their descent they were directed by lines fastened to the under edge of the bell, which passed through rings on both sides the leathern hose in each barrel; so that, sliding down by these lines, they came readily to the hand of a man,

who stood on the stage on purpose to receive them, and to take up the ends of the hose into the bell. Through these hose, as soon as their ends came above the surface of the water in the barrels, all the air, that was included in the upper parts of them, was blown with great force into the bell; while the water entered at the bung-holes below, and filled them: and as soon as the air of one barrel had been thus received, upon a signal given, that was drawn up, and at the same time the other descended; and, by alternate succession, furnished air so quick, and in so great plenty, that I myself have been one of five, who have been together at the bottom in nine or ten fathoms of water, for above an hour and half at a time, without any sort of ill consequence: and I might have continued there as long as I pleased, for any thing that appeared to the contrary. Besides, the whole cavity of the bell was kept entirely free from water, so that I sat on a bench, which was diametrically placed near the bottom, wholly dressed, with all my clothes on. I only observed, that it was necessary to be let down gradually at first, as about twelve feet at a

time; and then to stop and drive out the water that entered, by receiving three or four barrels of fresh air, before I descended farther. But being arrived at the depth designed, I then let out as much of the hot air that had been breathed, as each barrel would replenish with cool, by means of the cock at the top of the bell; through the aperture of which, though very small, the air would rush with so much violence, as to make the surface of the sea boil, and to cover it with a white foam, notwithstanding the weight of the water over us.

“ Thus I found, that I could do any thing, that required to be done just under us; and that, by taking off the stage, I could, for a space as wide as the circuit of the bell, lay the bottom of the sea so far dry, as not to be over shoes thereon. And by the glass window so much light was transmitted, that, when the sea was clear, and especially when the Sun shone, I could see perfectly well to write or read; much more to fasten or lay hold of any thing under us, that was to be taken up. And by the return of the air-barrels, I often sent up orders, written with an iron pen on small plates of lead, directing

how to move us from place to place as occasion required. At other times, when the water was troubled and thick, it would be dark as night below; but in such cases I have been able to keep a candle burning in the bell as long as I pleased, notwithstanding the great expense of air necessary to maintain flame.

“ By an additional contrivance, I have found it not impracticable for a diver, to go out of an engine to a good distance from it, the air being conveyed to him with a continued stream, by small flexible pipes; which pipes may serve as a clew, to direct him back again, when he would return to the bell.”

This ingenious contrivance of Dr. Halley, however, is liable to two inconveniences.—The raising of the bell depends entirely on the persons on board the vessel; and as it has a very considerable weight, even when in water, it requires a great deal of labour; but when it comes to be raised out of the water, the strain upon the ropes is very great, and if they should break, the persons in the bell must inevitably perish. Besides, the bottom of the sea is in many places rendered uneven by rocks; and if one of the

edges of Dr. Halley's bell should light upon a rock, the bell would infallibly be overset, before a signal could be made to the persons above.

To obviate these dangers, Mr. Spalding took a very simple, easy, and ingenious method. His bell, like Dr. Halley's, is a truncated cone of wood, but not coated with lead. Round the lower part are suspended leaden weights, sufficient to keep the mouth of the bell always parallel with the surface of the water, whether the whole machine be heavier or lighter than an equal bulk of water, but not sufficient to sink the bell. To effect this, another weight is added, which is suspended from the centre of the bell in the inside by a pulley, so that it can be raised or lowered at pleasure by the person within. Thus it is obvious, that, if the ropes above break, or the machine should be in danger of being overturned by a projecting rock at the bottom of the sea, the person or persons within may immediately stop it's descent, or allow it even to rise to the surface, by lowering the weight appended to the pulley.

Unfortunately, in June, 1783, Mr. Spalding went down in Dublin bay, with another gentleman, to survey the wreck of an imperial Eastindiaman, sunk in seven fathom water, when they both perished. As they had been down three times the day before, the fatal accident was probably owing to their not being duly supplied with air by their assistants above, who were certainly negligent, for it appeared afterward, on a legal examination into the affair, that the signal ropes were entangled.

CHAP. XXXIX.

OTHER CONTRIVANCES FOR DIVING.

DIFFERENT persons, at various times, have invented other means, to enable them to remain under water, but not equally useful and effectual with the diving-bell, though they deserve to be briefly noticed.

We read, that the divers in the Mediterranean used to take in their mouths a sponge

soaked in oil, to enable them to remain longer under water. At least so it is said; though it is very probable, that the oil was for the purpose of smoothing the water over them, to enable them to see objects clearly.

In Vegetius's book on the Art of War are some figures by the editor, but not explained in the work itself. Among these one represents a method of catching fish with the hand at the bottom of the sea. The diver has his head inclosed in a case, which will not admit water; and to the case is annexed a long leathern pipe, the aperture of which floats on the surface, so that the diver may take breath through it. Little, however, can be expected from a contrivance like this, particularly where the depth is considerable.

Another contrivance, which seems to be an improvement on the former, consists, like it, of a case for the head, but furnished with two tubes, both opening above the water. Through one of these fresh air is blown in by means of a pair of bellows, while the spoiled air is let out through the other; so that a circulation is kept up, by means of

which the diver has a constant supply of good air in his cap. This too can be of little service, especially in great depths: though the plan seems not altogether erroneous, and perhaps might be united with that of the diving-bell, as by Dr. Halley, to some advantage. The pipes, it is true, must be of considerable length, not too small, and kept distended by some means, as by rings at short distances on the inside, to prevent the pressure of the water from closing up the passage.

A scheme not different in principle, indeed, from the diving-bell, may be seen in a book on fortification, written by an Italian, named Lorini, and published in the beginning of the seventeenth century. This machine consists of a square box, cased with iron, and furnished with windows, and a seat for the diver.

The method adopted by a gentleman of Devonshire appears to be superiour to any of these, and on some occasions perhaps preferable to the diving-bell itself. He has a large case of strong leather, perfectly water-proof, which will hold about half a hoghead of air. This is so contrived, that, when shut up in it, he can walk at the bottom of

the sea, go into any part of a vessel, that is wrecked, and take out the goods. By means of this machine, which he has used for a number of years, he is said to have acquired a large fortune.

But all these experiments are trifling in magnitude compared with that of Cornelius Drebbel, who, about two centuries ago, constructed a vessel, which was rowed along under water in the Thames, with several persons on board. And it was but in the year 1774, that a mechanic of the name of Day had a ship built at Plymouth, in which he went down under water, and, after staying twelve hours, rose again, by letting loose some weights, that were fastened to the ship's bottom. On a second trial, however, in twenty-two fathoms water, Mr. Day was not so successful: for, whether the ship were overturned by the unevenness of the bottom, so that he could not disengage the weights; whether the machinery were injured, so that it would not take effect; or whether any thing happened to himself within, as faintness, or drowsiness, that rendered him unable to act; he perished at the bottom of the sea, the ship never appearing again.

CHAP. XL.

ACCOUNTS OF SWIMMERS AND DIVERS.

THE people of the South-Sea islands, with whom we have become acquainted through the means of modern voyagers, are particularly expert in swimming and diving. At Otaheite men and women swam off to the ships, which lay out at some distance from the shore, and sported about them like amphibious animals. Beads, nails, and other small heavy bodies, thrown out of the ship into the sea, they caught before they reached the bottom. They seem, indeed, to be nearly as much in their own element in the water, as on land: the children are accustomed to it from an early period, learn to swim almost as soon as to walk, and acquire such dexterity by daily practice, that they can continue on the water for hours together.

When Surville, a celebrated french navigator, was at the Bassée islands, in 1769, he detained several of the natives as prisoners, on account of some misunderstanding, that

arose. The sailors tied their hands behind their backs, and were conducting them to the captain's cabin; when some of them had the boldness, to leap into the sea, bound as they were; and, to the astonishment of the french, they swam in this manner to one of their canoes, which was at such a distance, as to have nothing to fear from the ships.

At the Sandwich islands the principal persons had in their service particularly expert divers, to be employed by them on necessary occasions. In 1788 our seamen had a proof of the ability of the divers of the king of Owhyhee. Their cable having parted, they had lost the anchor in a considerable depth of water, and requested the king to send his divers to search for it. They came, and prepared themselves for the enterprise by certain ceremonies. Their canoes being come to the place where the anchor was supposed to lie, one of the chiefs distributed a portion of taro roots, in calabashes, to six men, who were about half an hour eating it. Another then gave three loud shouts, and waved a white cloth over his head. At this signal, the six men leaped into

the sea, and disappeared. Four of them came up again in about five minutes. The fifth remained one minute longer, and was nearly exhausted when he rose to the surface; but two men immediately caught hold of him, and lifted him into the canoe. Still there was nothing to be seen of the sixth, and he was given over for lost, when he appeared for a moment, but immediately sunk again. Three of the divers leaped instantly after him, and brought him up senseless. The blood gushed out of his mouth and nose; but after a time he recovered, and said, that he had found the anchor, and loosened the cable from it. He had been seven minutes and half under water. The anchor lay too deep, to be gotten up; the divers, however, were amply rewarded for their trouble. A few days after another anchor was lost, and recourse was had to the king's divers again. The former ceremonies were repeated, and they leaped into the water as before. On this occasion neither of them remained more than four minutes under water, and the anchor was not found. They were sent down a second time, but with no better success. At length the seamen hooked the

anchor, by dragging a grapnel along the ground, and thus discovered where it lay. Two of the divers then went down with a hawser three inches and half thick ; passed it through the ring of the anchor, in twenty fathoms depth of water ; and tied it as fast, as if they had been on dry land ; so that the anchor was hoisted up by it.

The divers employed in the fishery at Astracan remain about seven minutes under water. Gmelin, in his travels through Russia, gives the following account of the painful toil of these poor people. " The Astracan divers go from the warm bath into the Wolga, in which they cannot remain above seven minutes ; coming out frozen and benumbed, they are carried back to the warm bath, from which they must return again to the river. This alternation of heat and cold they must repeat at least five times in the day, till at last the blood gushes out of their nose and ears, and they are brought back half dead."

From these accounts it should seem, that an expert diver can remain under water from five to seven minutes only, without artificial helps : yet it is said, that the art of diving

may be carried to a much greater length. Even in ancient times divers were employed, to assist in getting up anchors, to recover goods that were sunk, or in time of war to injure the ships or works of an enemy. When Alexander laid siege to Tyre, the divers swam from the city to some distance under water, and with long hooks tore down the works, which the enemy were erecting, to block up the harbour. Herodotus records, that a diver, named Scyllias, could swim under water, or walk at the bottom of the sea, for two miles, without taking breath.

The divers for pearls are certainly the ablest in modern times, at least, as will appear from the following account of the pearl-fishery in the East Indies.

At the beginning of the season, which is every spring and autumn, there are sometimes two hundred and fifty vessels assembled on the banks, where the pearl-muscle is found. The larger vessels have two divers, the smaller one. The vessels having anchored, each diver binds a stone, six inches thick, and a foot long, under his body, to serve him as ballast, prevent his being driven away by the motion of the water, and enable him to

walk more steadily under the waves. He also ties another very heavy stone to one foot, which carries him speedily to the bottom of the sea. As the muscles in general adhere firmly to the rocks, his hands are usually defended with leathern gloves, to prevent them from being wounded, in tearing off the fish; or else he is provided with an iron rake for the purpose. He likewise carries down with him a large net, hung round his neck by a cord, the other end of which is fastened to the side of the vessel. This net is to hold the muscles gathered from the rock; and the cord is to pull up the diver, when his net is full, or when he wants air.

Thus equipped, he dives sometimes to the depth of sixty feet; and, as he has no time to lose, as soon as he arrives at the bottom, he runs from side to side, tearing up all the muscles he finds, and cramming them into his net.

At whatever depth the diver is, the light is so great, that he easily sees whatever passes in the sea; and sometimes to his great consternation, he perceives monstrous fishes, from which his utmost address, in muddying the water, &c. cannot always save him, so that

he unhappily becomes their prey. Of all the dangers of the fishery, this is one of the greatest, and most usual.

The best divers will keep under water near half an hour, and the rest do not stay less than a quarter. During this time they hold their breath without the use of oils, or any other liquors, only acquiring the habit by long practice. When they find themselves in want of air, they pull the rope, to which the bag is fastened, and hold fast by it with both hands. On this signal, the men in the vessel draw them up by the rope, and unload them of their muscles, which may be sometimes five hundred, at others not above fifty. Some of the divers require a short respite, to recover breath; others jump in again immediately, and continue this violent exercise for several hours without intermission.

Thus we find it is by no means uncommon, where the art of diving is pursued with ardour, to find men capable of remaining under water for fifteen minutes, or even half an hour; or of diving to the bottom, and performing things there, at the depth of a hundred and twenty feet, or more. But it

is said, that there have been people, capable of still more than this. The most remarkable instance we have, at least in which any confidence can be placed, is that of the famous Sicilian diver, Nicolo Pesce. The authenticity of the account, indeed, depends on the authority of father Kircher; who assures us, that he had it from the archives of the kings of Sicily. Undoubtedly there is a little exaggeration in some parts of the tale, yet upon the whole it is certainly far from incredible. The following is Kircher's narrative.

“ In the time of Frederick king of Sicily, there lived a celebrated diver, whose name was Nicholas; and who, from his amazing skill in swimming, and capacity of continuing under water, was surnamed the *Fish*. This man had been used to the sea from his infancy; and earned his scanty subsistence by diving for corals and oysters, which he sold to the villagers on shore. His long familiarity with the sea at length brought it, to be almost his natural element. He was frequently known to spend five days in the midst of the waves, without any other provision than the fish, which he caught there, and ate raw.

He often swam over from Sicily to Calabria, a tempestuous and dangerous passage, carrying letters from the king. He was frequently known to swim among the gulfs of the Lipari islands, not in the least apprehensive of danger.

“Some mariners out at sea one day observed something at a distance, which they regarded as a sea-monster; but upon it's approach, it was known to be Nicholas, and they took him into their ship. When they inquired, whither he was going in so stormy and rough a sea, and at such a distance from land, he showed them a packet of letters, which he was carrying to one of the towns of Italy, safely enclosed in a leathern bag, so that they could not be wetted by the waves. He kept them company for some time, conversing, and asking them questions; and after eating a hearty meal with them, he took his leave, jumped into the sea, and pursued his voyage.

“Nature seemed to have assisted his powers of continuing on the deep in an extraordinary manner; for the spaces between his fingers and toes were webbed, as in a goose; and his chest became so very capacious, that

he could take in, at one inspiration, as much breath as would serve him for a whole day.

“ The account of so extraordinary a person did not fail, to reach the king himself; who commanded Nicholas, to be brought before him. It was no easy matter, to find Nicholas, who generally spent his time in the solitudes of the deep; but, at last, after much searching, he was found, and brought before his majesty. The curiosity of the monarch had long been excited by the tales he had heard of the bottom of the gulf of Charybdis; and he now conceived, that it would be a proper opportunity, to obtain more certain information. He therefore commanded the poor diver, to examine the bottom of this dreadful whirlpool; and as an incentive to his obedience, he ordered a golden cup to be flung into it. Nicholas was not insensible of the dangers, to which he was exposed, dangers best known to himself, and therefore he presumed to remonstrate: but the hopes of the reward, the desire of pleasing the king, and the gratification of showing his skill, at last prevailed. He leaped into the gulf, and was instantly swallowed up in it's bosom. For three quarters of an hour

he continued under water; during which the king and his attendants remained on shore, anxious for his fate. At length he appeared, holding the cup triumphantly in one hand, while with the other he made his way through the waves. It may be supposed, he was received with applause, when he came on shore. The cup was made the reward of his adventure; the king ordered proper care to be taken of him; and, as he was somewhat fatigued and debilitated by his labour, after a hearty meal he was put to bed, and permitted to refresh himself by sleeping.

“ When he had thus recruited his spirits, he was again brought before the king, to gratify his curiosity with a narrative of the wonders he had seen, and his account was to the following effect. After saying, that he would never have obeyed the king's commands, had he been apprised of half the dangers, to which he exposed himself, he added, that there were four things which rendered the gulf dreadful, not only to men, but even to fishes themselves. These were, 1, the force of the water bursting up from the bottom, which required great strength to resist: 2, the abruptness of the rocks, on

every side threatening destruction: 3, the force of the whirlpool dashing against these rocks: 4, the number and magnitude of the polypi, some of which appeared as large as a man, and which, every where sticking against the rocks, stretched out their fibrous arms, to entangle every thing, that came near them. Being asked, how he was able, so readily to find the cup, that had been thrown in, he replied, that it happened to be thrown by the waves into the cavity of a rock, against which he himself was driven in his descent.

“ This account, however, did not satisfy the curiosity of the king. Being requested, to venture once more into the gulf for farther discoveries, he at first refused: but the king, desirous of having the most exact information possible of all things to be found in the gulf, repeated his solicitations; and, to give them still greater weight, produced a larger cup than the former, to which he added a purse of gold. These temptations were too powerful for the unfortunate diver, he plunged again into the whirlpool, and was never heard of more.”

As Nicholas was celebrated for his capacity

of remaining under water, Paul Moccia, a neapolitan priest, was famous for being totally incapable of diving. This man, though well made, was bulky and fat. He weighed two hundred and thirteen pounds avoirdupois; and it was found by Joseph Dies, the mathematician, that this was twenty pounds and a quarter less than an equal bulk of water would have weighed. Thus it appears by the laws of hydrostatics, as explained in a preceding part of this volume, that he would not sink of himself, but swim upright like an hydrometer. He was ignorant of the property he possessed, till he was advanced in life, when he discovered it, on attempting to dive when bathing. He then made the experiment of letting himself float in the sea, and found it succeed: and getting two divers, to drag him down under water by the feet, as soon as they let go, he rose to the surface spontaneously, and remained with his head and shoulders above water. When the sea was smooth, he could go about in it wherever he pleased, by slightly moving his hands; and he could eat and drink, read, write, or the like, in the water.

It is probable, that many fat persons have

no greater specific gravity than this italian ; but as those who are corpulent seldom take much delight in swimming, they remain ignorant of the faculty they possess.

CHAP. XLI.

VENTRILOQUISTS.

MOST people are contented, to employ their faculties in the ordinary way, fully satisfied, if they answer the purposes of common life ; and have no conception of what may be effected, by assiduous cultivation, or bending them to any particular purpose. The dexterity acquired by various mechanics in the employments in which they are constantly engaged is astonishing to other people ; and while most men unused to the water begin to stifle, if immersed in it for half a minute, we find others have brought their lungs by practice, to dispense with the inhalation of fresh air for half an hour.

Thus the lungs and vocal organs of the ven-

triloquist appear to be extraordinarily subservient to his will; and we are the more surprised at his performances, because few have thought it worth while, to cultivate a faculty, that is applicable to no useful purpose.

To form words, men usually expel the air from the lungs through the windpipe with more force, than in ordinary breathing; and at the same time contract the glottis, or upper part of the windpipe, so that the air, issuing out at a narrower passage, occasions a sound, more or less loud, which is the voice. As the voice passes out through the mouth, it is variously modified by changing the figure of this cavity; which is effected chiefly by means of the tongue and lips: and thus articulate sounds are produced, or words formed. If gentle breathing alone be employed, and modified by the tongue and lips, without contracting the glottis, and forcing out the air so as to produce a loud voice, it is called whispering. This whispering is more or less loud, according as the breath is emitted with more or less strength: but it must issue with somewhat more force than in ordinary breathing, otherwise the sound will not be audible. This we com-

monly find in young children, when they first attempt to whisper; they move their lips, but no articulate sound is heard.

In speaking, the air issues chiefly through the mouth; yet partly, in articulating certain letters, through the nose also. When the nostrils are held close, or accidentally stopped, we can speak, though with a different tone. This tone, which is very disagreeable when in a high degree, is called speaking through the nose: and not altogether improperly; for though the voice cannot issue through the nose, when the nostrils are closed, this sound is formed in the nose, whether the nostrils be stopped or open. When this defect is avoided, the nose conduces much to improve the tone of the voice; as any one will find, who first pronounces a sentence clearly and deliberately with his nostrils open, and then, stopping his nostrils, speaks the same words without suffering any breath to enter his nose.

The mouth, however, is so essential to speaking, that, though different sounds may be made with the lips shut, no articulate voice can be produced, while the lips are close. If, indeed, there be a small aperture

left between the lips, so that the air can issue out between them, many words may be spoken intelligibly, though with no very harmonious tone: but it is perhaps impossible, to articulate some of the consonants, without moving the lips more or less.

Sounds may be formed, and words uttered, not only when air is forced out through the mouth, but also when it is drawn in. This, however, is much more difficult.

There have been people, in different ages, whose internal organs of speech were so flexible, and who had such skilful command over them, that they have been capable of articulating, and holding conversations, without any movement of their lips being perceptible. In such cases it is obvious, that the sound of the voice must differ from what it would be in the usual way. Most commonly it would have a somewhat obscure and hollow sound, and hence was supposed by those, who did not know how it was produced, to be formed in the belly. On this account such people were mistakenly called ventriloquists, or speakers from the belly, and this name is still retained.

The feats, that these people are said to

have performed, seem much more surprising in the narratives given of them, than they are in fact, when the whole of the business is understood. Perhaps my young readers will be best enabled to form an adequate idea of the subject, by being first told what they have done, and then instructed how to account for the performance.

At Saint Germain-en-Laye, ten miles from Paris, lived a shop-keeper, whose name was Saint-Gille, a very ingenuous and honest man. At Martinico he had learned from an intimate friend the art of ventriloquism in the space of a week, and had made himself a great master in it by practice. Of this faculty he made no ill use, neither did he employ it as the means of getting money: he used it only to divert himself and his friends, and made no secret of the talent he possessed.

The abbe de la Cappelle, having heard many wonderful things of this man, was desirous of being convinced of the truth by means of his own ears. Procuring an introduction to Mr. Saint Gille, he expressed to him his wishes; and was taken by him into a back parlour, where they both sat down

by a small fire, with a table between them. The abbe fixed his eyes the whole time steadfastly on Mr. Saint Gille, who entertained him for half an hour with laughable anecdotes, to which his art had given birth. On a sudden the abbe heard himself called by his name and title, by a voice which seemed to come from the roof of a neighbouring house. He was surprised, but soon guessed at the deception, and asked Mr. Saint Gille, whether he were not giving him a specimen of his art. He was answered only by a smile, and looking toward the house, from which the sound appeared to proceed, a voice seemingly in the corner of the room called out "not there." In this manner the artificial voice played round him, seeming to come from different distances, and various places, as the artist thought proper. Notwithstanding the abbe was fully prepared for this, and knew it to be the voice of a man sitting opposite to him, the deception was so complete, that he could not bring his senses to form a true conception of the place, from which the sound actually issued. When Mr. Saint Gille displayed his art, he appeared to be perfectly silent,

and not the least alteration was visible in his countenance. The abbe observed, however, that he turned his face a little, though with perfect ease, and no appearance of design, so that one side of it only was to be seen, when he spoke as a ventriloquist.

The following anecdotes are selected from many related of this gentleman.

Mr. Saint Gille, returning home from a place, to which he had gone on business, sought shelter from an approaching thunder storm in a convent. Finding the whole community in mourning, he inquired the cause, and was told, that one of their body had died lately, who was the ornament and delight of the whole society. To pass away the time, he walked into the church, attended by some of the friars, who showed him the tomb of their deceased brother, and spoke feelingly of the scanty honour, they had bestowed on his memory. Suddenly a voice was heard, apparently proceeding from the roof of the choir, lamenting the situation of the defunct in Purgatory, and reproaching the brotherhood with their lukewarmness and want of zeal on his account. The friars, as soon as their astonishment gave them

leave to speak, consulted together, and agreed to acquaint the rest of the community with this singular event, so interesting to the whole society. Mr. Saint Gille, who wished to carry on the joke, dissuaded them from taking this step; telling them, that they would be treated by their absent brethren as a set of fools and visionaries. He recommended to them, however, the immediate calling of the whole community into the church, where the ghost of their departed brother might probably reiterate his complaints. Accordingly all the friars, novices, lay brothers, and even the domestics of the convent, were immediately summoned, and assembled together. In a short time the voice from the roof renewed it's lamentations and reproaches, and the whole convent, falling on their faces, vowed to make a solemn reparation. As the first step they chanted a *De profundis* in full choir; during the intervals of which the ghost occasionally expressed the comfort he received from their pious exercises and ejaculations in his behalf. When all was over, the prior entered into a serious conversation with Mr. Saint Gille; and, on the strength of what had passed,

sagaciously inveighed against the absurd incredulity of our modern sceptics, and pretended philosophers, on the article of ghosts and apparitions. Mr. Saint Gille thought it now high time, to disabuse the good fathers. This, however, he found it extremely difficult to effect, till he had prevailed upon them, to return with him into the church, and there be witnesses of the manner, in which he had conducted this deception.

Once, to put the art of Mr. Saint Gille to the test, he was prevailed upon, to exhibit a specimen of it to a large company, consisting of a committee of the academy of sciences, and several persons of rank. A day was appointed for the company, to dine in the wood of Saint Germain-en-Laie. All the party were in the secret, except a lady, whom the abbe Chapelle mentions only as the countess de B—. This lady was to be the butt of Mr. Saint Gille's deceptive art. She was told, there was a report, that an aerial spirit had taken up it's residence in the wood of Saint Germain-en-Laie, in consequence of which a numerous deputation from the academy of sciences was to be sent, to spend

a day in the wood, in order to investigate the truth of this relation.

Mr. Saint Gille, as may be supposed, was not omitted among the guests. Before he joined the company in the wood, he completely imposed upon one of the learned deputies of the academy, who had parted from the rest, and accidentally fell in with him on the way. Prepared as he was, and on his guard against all deception of the kind, he thought, without the least suspicion, just as Mr. Saint Gille came up to him, that he was called to come back in great haste by Mr. de Fouchy, who was with the rest of the company more than a hundred yards distant. His servant, too, heard the supposed call, told his master of it, and, turning toward the company, bawled out as loud as he could to Mr. de Fouchy, "yes, sir!"

The company being seated at table, the spirit, who was previously acquainted with some private anecdotes relative to certain of the persons present, began to make himself heard. Sometimes the voice seemed to descend out of the air overhead, at other times

to rise from the ground, being chiefly addressed to the countess de B—, to whom, as well as to the rest of the ladies, it paid many compliments. This entertainment continued for a couple of hours. The countess, who perhaps might be a little inclined to credulity, was fully convinced, that it was the voice of a spirit; and was not a little vexed, when the deception was disclosed.

Another time Mr. Saint Gille went to take a walk in this same wood with an officer, who always carried his head very erect, and his chest projecting, with a strutting gait, and never spoke a word, unless battles or sieges were the subject of conversation. As they came to an open spot, a voice called out, seemingly from behind a tree: "it is not every one, who wears a sword, that has the heart to use it."

"What impudent rascal's that?" exclaimed the officer.

"Some bird-catcher, I dare say;" returned Mr. Saint Gille in his natural voice; "perhaps taking a nest of young birds: but let us go on."

The officer shook his head, and looked very sour.

"You dare not wait for me:" said the voice from the tree.

"Yes, if you will show yourself:" replied the officer, setting his hat, and laying his hand upon his sword.

"What do you mean?" said Mr. Saint Gille, in his natural voice, again, holding him back; "it is only some one, that wants to laugh at you."

"A valiant posture is not always a sign of courage:" rejoined the voice, which had seemed to descend from the summit of the tree, till now it was at the bottom.

"That's no bird-catcher;" said the officer in a fury. "I'll make him repent his impudence."

With this he drew his sword, and made a thrust into the bush, at the bottom of the tree, where he supposed the enemy to be concealed. A rabbit, that lay there, leaped out, and ran away.

"See," said Mr. Saint Gille with a laugh, "what a hero you have put to flight! Why do you not see whom your enemy is, before you make your attack? but your head is so full of battles and bloodshed, that, like don Quixote, you had rather fight with bushes

or rabbits, than not take occasion to draw your sword."

As a rival to Mr. Saint Gille may be mentioned baron Ferdinand von Mengden, of Horde, a lieutenant colonel, and a man of great understanding, who resided at Vienna about twenty years ago, and was celebrated for his skill in ventriloquism.

This gentleman had a little doll, the lower jaw of which the person who held it could set in motion at will, by an ingenious mechanical contrivance, so that it appeared as if talking. When he wished to amuse a company, he would hold a conversation with this doll, and jest with her, till commonly the doll would at last grow so impudent, that he would put her into his pocket, from which she would complain bitterly to the company of his severe treatment.

Being once at the court of Bayreuth, he was amusing the prince of Zweybrueck and some other persons of rank with this puppet, who could not conceive, how he managed the business. An Irish officer, who was present, was firmly persuaded, it must be some living creature, that had been taught to speak in this manner, if it were nothing

worse. When the dialogue was ended, and the baron von Mengden had put the doll into his pocket, the irish officer attempted to take her out. The little thing, as if in great danger, cried out for assistance, and continued screaming from the pocket, till he desisted; when she was silent. The baron then took out the doll himself, and showed her to the company, to convince them all, as well as the officer, that it was nothing but a piece of wood.

There was lately at Paris a ventriloquist, who exhibited on the stage, by the name of Fitz-James. It is said, that, dining one day at an eating house with some friends, he gave them a diverting specimen of his art. In the middle of the room was a stove, the funnel of which communicated with a chimney, that had been stopped up. The table, at which he sat, was by the side of the chimney, and he pretended to hold a conversation with some one shut up in it. The company listened in surprise. The master of the house was alarmed, and the women ran to call the guard. From the dialogue, which Fitz-James kept up, it would have appeared, that a thief had contrived to get down the chim-

ney, but was unable to return; and being ready to die with hunger, confessed his crime, and begged to be released: choosing rather to undergo the punishment, which he confessed he deserved, than to be starved to death. The guard arrived: the captive was questioned: he answered very penitently; and it was proposed, to pull down the wall, that closed the fireplace. While this was debating, Fitz-James had removed, and stationed himself near the stove. On his speaking again, every person present imagined, that the thief had contrived to creep into the stove through the funnel, small as it was. This could not fail to excite their astonishment. However, it was now time, to end the joke. Fitz-James avowed the deception he had practised; the guard retired laughing; and the company, much amused, resumed their places.

Many of my readers, probably, have heard Mr. Askins, the ventriloquist, who has performed within these few years at Sadler's Wells, and in different parts of the country. This man carries on a dialogue with a puppet, which he dances on his knee, holds in his arms, or puts into his pocket. He will also

count twenty, without the least motion of his lips, or a single muscle of his face; a candle being held just by his mouth during the time, that the spectators may be convinced they remain unmoved.

This, the acquiring a habit of articulating without moving the lips, is the chief circumstance in the art of ventriloquism. If the lips be left with an almost imperceptible opening between them, it is not very difficult, to pronounce most of the letters with tolerable distinctness, the labials excepted. These the artful ventriloquist endeavours to avoid, by using words into which they enter as little as possible. When he does use them, he contrives to conceal the motion of his lips, which may be very trifling, if the opening left between them be extremely slight, by looking a little downward perhaps; or by turning his face on one side, as Mr. Saint Gille appears to have done. For it is to be observed, that the labials may be formed wholly on one side of the mouth, the lips on the other side remaining close. Of this probably Mr. Askins likewise avails himself, when he speaks to his little puppet, now in the right hand pocket, now in the left. Be-

sides, at the distance at which he is seen, and by candle-light too, a slight motion of the lips would not be very easily perceptible.

It is to be observed, likewise, that the assistance of the eye is called in, to deceive the imagination. The ventriloquist has a puppet, with which he pretends to converse. The spectator hears a man speak in his natural voice. This speech is answered in a different key, in a kind of squeaking tone. It is natural for the spectator, to refer this voice to another person, particularly as the performer's countenance remains unmoved, like that of one listening, not like that of a person speaking. Now there is nothing but the puppet present, to which the spectator can refer the voice, and this it's shrillness suits: is it to be wondered, therefore, that he imagines he hears the sound come from the puppet?

In this case, if the ventriloquist be sufficiently master of his art, to speak without moving or being seen to move his lips, nothing more is necessary: the speaking voice will naturally seem to come from the puppet; for the puppet and the man being close to-

gether, the sound may justly be considered as issuing from the same spot. Fitz-James, too, it is to be remarked, when in the eating house, took care to station himself near the spot, from which the voice was supposed to issue; and this spot was a hollow, enclosed place, which, it may be presumed, well suited his fictitious voice, issuing from a nearly closed mouth.

On other occasions, as in the anecdotes related of Mr. Saint Gille, more skill on the part of the ventriloquist appears to have been requisite; though a skill by no means unattainable. Sounds differ according to the distance from which they proceed, and the direction in which they strike our ears: a ventriloquist, who can judge of the effects, that distance and direction produce on sound, and has acquired a capacity of modulating his artificial voice accordingly, may produce almost any deception of this kind. Besides, we are little used to remote sounds, or rather to judge of them with any degree of accuracy; so that in this, as in most other things, our own ignorance and negligence promote our being deceived. Mr. Saint Gille's performers, too, were on one occasion a ghost,

on another an aerial spirit ; and the auditors would naturally suppose, that such immaterial being must speak in a tone somewhat different from that of the human voice, which would facilitate his task.

In most of these instances, as is generally the case, it is chiefly our own senses, that deceive us : and hence we should learn, not to rely on them with too much confidence ; at the same time endeavouring, by attention and assiduous cultivation, to render them as accurate as possible, that they may not be too liable to mislead us. The negligence of some with respect to the most common of our senses, is strikingly depicted in the pleasing tale of Eyes and no Eyes, in Evenings at Home ; and those, who would wish to improve the different senses, we would refer to Salzmann's Gymnastics for Youth, a book, which we have before had occasion to mention.

8 JUL 58

END OF THE SECOND VOLUME.

